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HOW IT WORKS

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SCIENCE

⚙️ Are we still evolving?



TECHNOLOGY

⚙️ Epic engineering projects



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SUPERYACHTS

How these luxury vessels are built

MEGASHARKS

Meet the monstrous
whale eaters that
ruled prehistoric
oceans

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of razor-
sharp
teeth

Epic 18-ton
bite force

Ruthless
whale hunters

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MONT SAINT-MICHEL

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SAVING EARTH

FROM SPACE

FUTURE

ISSUE 114

TWO GREAT SHOWS TOURING THE COUNTRY!

**'IT'S
SO MUCH
BETTER
THAN THE
BOOK!'**
DAVID
WALLIAMS

David Walliams **GANGSTA GRANNY**



'TOTALLY GRANTASTIC!'

MAIL ON SUNDAY



David Walliams **Awful AUNTie**

**LIVE
ON
STAGE!**



**'ANOTHER HUGE
DRAMATIC HIT!'**

WHAT'S ON LIVE



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WELCOME

ISSUE 114

The magazine that feeds minds!



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Sharks have been around for at least 420 million years, predating and out-living the dinosaurs. During that time they have evolved into a variety of fearsome species, but none were bigger than the monstrous megalodon. At up to 18 metres long, with a mouth packed full of huge, super-sharp teeth, it was one of the biggest predators Earth has ever seen.

Sometimes it's not the biggest species that do the most damage. There are hundreds of plants and animals wreaking havoc on habitats they've been unnaturally introduced to. Find out more about these invasive aliens in our environment feature.

Also inside, we reveal some epic engineering projects, step aboard a superyacht and discover how humans are still evolving. Enjoy the issue!

Jackie **Jackie Snowden**
Editor



"From orbit we can predict environmental changes and even fix problems..."

Saving Earth from Space, page 44

Meet the team...



Charlie G
Production Editor

The looming structures on page 52 are testament to the brilliance of today's architects and engineers. LEGO was my limit!



Baljeet
Research Editor

Are we alone? It's a question that we still haven't managed to answer. Learn about NASA's attempts to find Earth 2.0 on page 50.



Charlie E
Staff Writer

This month we went below deck to find out what it takes to build a superyacht. If beautiful boats are your thing then sail over to page 74.



Scott
Staff Writer

This issue, Charlie E and I explored our genetic ancestry with the help of 23andme. Find out how scientists discover who you are on page 40.



Duncan
Senior Art Editor

Having watched *Jaws* around 563 times and being a huge shark fan, it's scary to think a shark big enough to eat whales with one chomp existed!

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Epic engineering

MEET THIS ISSUE'S EXPERTS...



Ella Carter

With a marine science degree, Ella is fascinated by our oceans. She writes about all realms of the natural world, from blue whales to barnacles.



James Horton

Former **HIW** member James is a biochemist and biotechnologist. He is currently doing a PhD in machine learning and evolutionary theory.



Jo Stass

Jo has been a writer and editor for over six years. She is particularly interested in the natural world and technological innovations.



Jodie Tyley

The former editor of **HIW** and **All About History** has tackled many topics in her career, from science fiction to science fact and Henry VIII to honey badgers.



Jonathan O'Callaghan

With a background in astrophysics, former **HIW** and **All About Space** journalist Jonathan enjoys delving into the wonders of space.



Laura Mears

Biomedical scientist Laura escaped the lab to write about science and is now working towards her PhD in computational evolution.



Stephen Ashby

Stephen has been a writer and editor for over seven years. He is endlessly intrigued by technology and Earth science.



Steve Wright

Steve has worked as an editor on many publications. He enjoys looking to the past, having also written for **All About History** and **History Of War**.



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REGULARS



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PAGE 95



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GREAT DEALS



**Tim
Williamson**
History Of War
Editor Tim has a passion for all things military but studies and writes about a range of historical eras.



Tom Lean
Tom is a historian of science at the British Library working on oral history projects. His first book, *Electronic Dreams*, was published in 2016.





Antarctic ice caverns

A microbiologist takes soil samples to check for evidence of microbes beneath the frosty crystalline dome of an ice cave at Antarctica's Mount Erebus – the southernmost active volcano on Earth. Sunlight filters through the thin ice, illuminating the caverns with an eerie blue glow.



Reclaimed by nature

Houtouwan on Shengshan Island, China, was previously home to about 2,000 fishermen and their families, but since it was largely abandoned in the early 1990s the village has been taken over by plants. The ghostly, leaf-covered buildings have become a tourist attraction in recent years.



ENVIRONMENT

Forced to flee the daylight

A new study reveals that human activity is causing mammals worldwide to become increasingly nocturnal

As the human population continues to grow, so does the requirement for mammal species to adapt their behaviours to survive. A recent study published in the journal *Science* is the first of its kind to explore the changes to the daily activity patterns of mammals in response to human activity. The global research project focused on 62 species larger than one kilogram across six continents, including species such as deer, coyotes and even tigers.

The team from the University of California at Berkeley found that, on average, these mammals increased their nighttime activity by 36 per cent in response to human disturbance. This growing behavioural change could have many negative consequences.

"Animal activity patterns reflect millions of years of adaptation – it's hard to believe we can simply squeeze nature into the dark half of each day and expect it to function and thrive," said co-author Justin Brashares, a professor at UC Berkeley's Department of Environmental Science.

As mammals begin to shift to nocturnal patterns the fear is that these animals' foraging or hunting behaviour will be disrupted, leaving them more vulnerable to predation and increased competition from other species.

The nocturnal megazostrodon – widely accepted as one of the first mammals – is thought to have lived around 200 million years ago



The new dinosaurs

For their first 100 million years on Earth, it is thought that our mammal ancestors were nocturnal to avoid the wrath of their dinosaur predators and competitors. Only after the mass extinction event that led to the demise of these giant reptiles were mammals able to move from the dark and into the light, giving rise to the diurnal activity patterns humans and many other mammals exhibit today.

As human activity continually increases and our presence threatens mammals' way of life, are we becoming the new group of predators forcing those with fur back into the dark?



Data was collected using motion-triggered cameras, GPS, radio collars and direct observation

Different types of human disturbances -
from hiking and infrastructure to hunting
- are just some examples of how we are
affecting animals' activity patterns





Corals need algae to live in their tissues in order to survive, but if they're stressed they expel these organisms and slowly start to starve

Combating coral reef destruction

The primary stressors to coral reefs can be divided into natural and human-related factors. The conservation of coral reefs depends on damage limitation, using active management tactics and getting communities involved to help protect the ocean ecosystems.

Coral reefs are slow-growing specimens, taking up to 10,000 years to form and up to 30 million years to fully develop, so any damage or destruction can be devastating. Bottom trawling, blast fishing, hurricanes and cyclones can all destroy coral heads by breaking them apart or flattening them.

By designating more protected areas that promote less-damaging fishing tactics we can help preserve these ecosystems. Another conservation effort involves coral nurseries, which work to grow young corals and transplant them into reefs that are in decline.



The Great Barrier Reef is the largest coral reef in the world and is one of the most biodiverse habitats on Earth

A thriving coral reef supports the fish, crustaceans and other creatures that live within it

ENVIRONMENT

Small communities of coral reefs are flourishing despite a global decline

Understanding why these oases are thriving could help us save threatened ecosystems

The last 30 years has seen roughly 50 per cent of our planet's coral reefs destroyed, but new research suggests it might not all be doom and gloom. Despite the odds being stacked against them, small pockets of coral have been identified by researchers as either escaping, resisting or rebounding from the changes to their environment that threaten their survival. These robust ecosystems have successfully avoided the catastrophes that have decimated others, such as bleaching, hurricanes and the invasion of coral-eating sea stars.

Dr James Guest, lead author and currently a European Research Council Fellow at

Newcastle University, explained the theories behind these exceptional survival stories in a recent press release. "It could be that the location is simply better for survival – deeper water that is outside the storm tracks, for example. The coral communities could possess biological or ecological characteristics that make them more resilient and able to resist damage. Or there may be ecological processes at play that means that the reef community is able to rebound more quickly after a disturbance."

While coral reefs are suffering massive losses around the world, there is hope these hardy locations may offer an insight into how to protect the areas in danger of dying out.



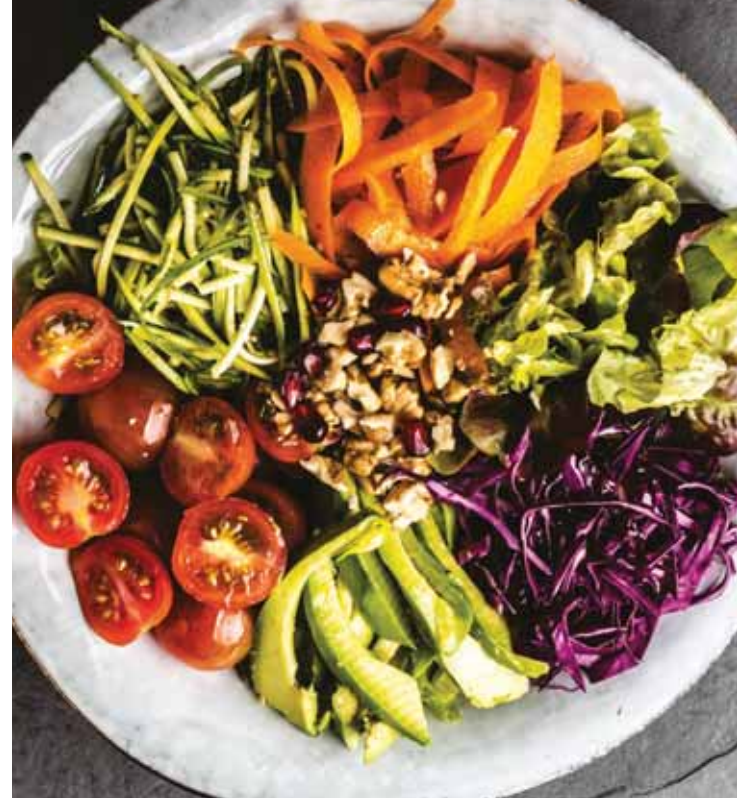
Plant-based diets focus on fruits, vegetables, grains and legumes

Plant-based diets could be beneficial for diabetics

Green diets could reduce cardiovascular health risks and tackle diabetes

After a review of nine different trials assessing veganism and vegetarianism in diabetic patients, researchers have discovered the potential health benefits of plant-based diets for those with Type 2 diabetes. The team found that, compared to meat-eating diabetics, those that were vegetarian or vegan tended to have lower cholesterol and reduced levels of glycated haemoglobin (an indication of average blood sugar levels).

"The link between diabetes and cardiovascular disease is strong. 60 to 70 per cent of people who have Type 2 diabetes die of heart disease," said co-author and director of clinical research at the Physicians Committee for Responsible Medicine Hana Kahleova. "The good news is that this study shows that the same simple prescription – eating a plant-based diet – can reduce our risk for heart problems and improve Type 2 diabetes at the same time," Kahleova added.



Prototype fusion reactor gets hotter than the Sun

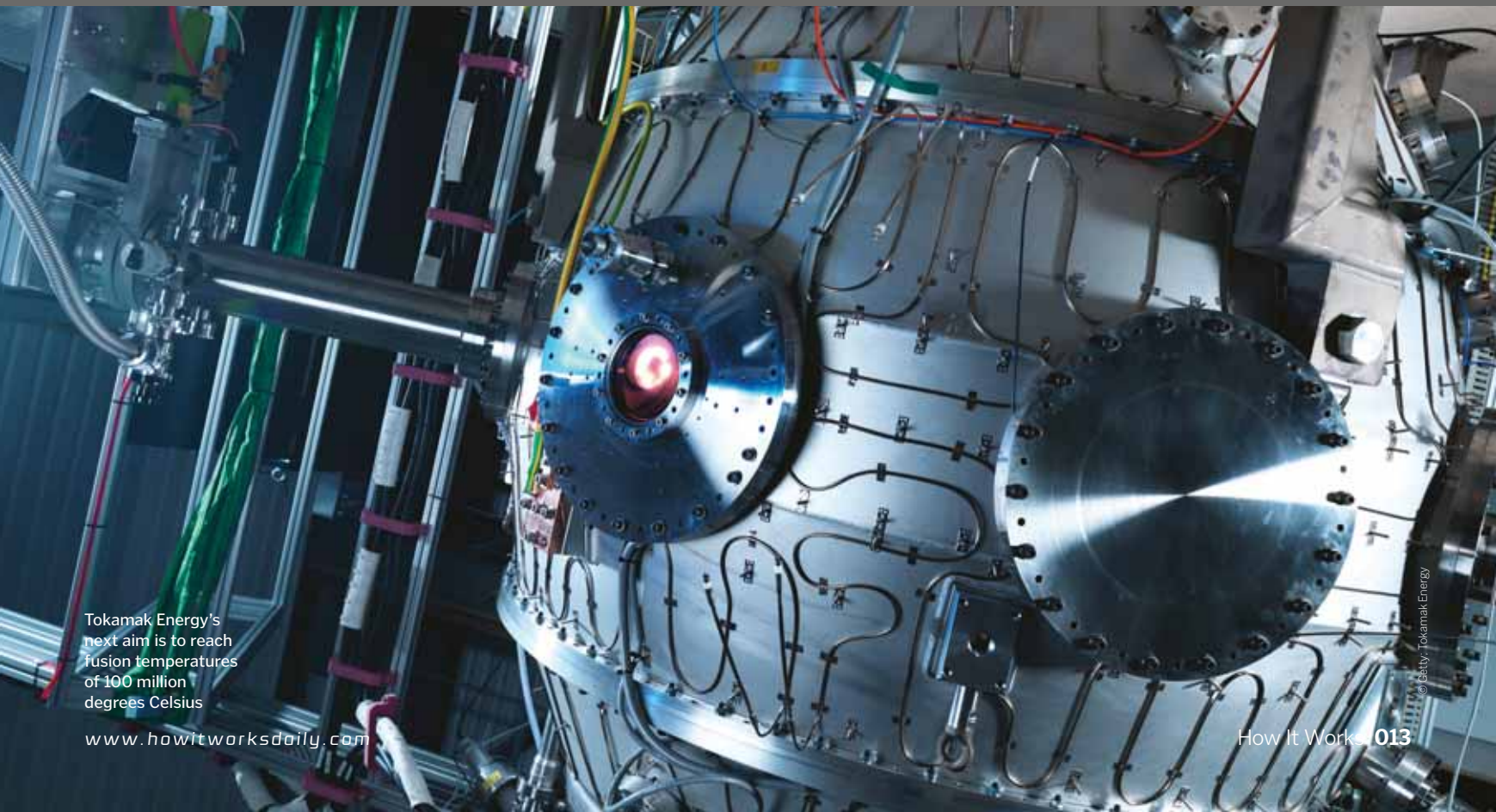
Could we be on our way to a fusion-powered future?

Created by Tokamak Energy, the ST40 spherical reactor aims to be the first privately funded fusion reactor. In order to achieve its goal of clean fusion, the ST40 needs to reach incredible temperatures to fuse particles together. The company

reached a recent milestone when the reactor fired up to over 15 million degrees Celsius – hotter than the centre of the Sun.

This achievement is a key step in reaching Tokamak Energy's goal of making fusion energy commercially viable by 2030. The

company's co-founder, Dr David Kingham, explains "The world needs abundant, controllable, clean energy. Our business plan is built on strong scientific foundations, and this milestone is a significant step in our compact spherical route to fusion power."



Tokamak Energy's next aim is to reach fusion temperatures of 100 million degrees Celsius

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SCIENCE

Sleeping too much or not enough may be damaging your health

If you are getting less than six hours or more than ten you could be at risk of metabolic syndrome

A new study from Seoul National University College of Medicine in South Korea has found that sleeping too much or not enough can put your health at risk. Metabolic syndrome is a collection of conditions that are associated with the development of cardiovascular disease, stroke and Type 2 diabetes. The study involved 133,608 Korean men and women aged between 40 and 69 and investigated why the prevalence of the disease is so high.

The team considered individuals to have the syndrome if they showed at least three of the following symptoms: larger waist circumference, high triglyceride levels, low

levels of healthy cholesterol, high blood pressure and high fasting blood sugar. The researchers conducted an extensive investigation into each participant's health, including their medical history, lifestyle factors, diet and physical activity. Sleep was identified as a common factor in many of those with the syndrome, but the team also spotted a potential gender difference in their results. Men who regularly slept for less than six hours, or women who sleep for more than ten hours, tended to have an increased risk.

The paper has not established the biological mechanisms behind this connection, but it has suggested that people

who sleep less than seven hours a day may have elevated levels of hormones that could increase their appetite, perhaps also reducing energy expenditure.

Lead author of the study Claire E Kim said, "This is the largest study examining a dose-response association between sleep duration and metabolic syndrome and its components separately for men and women. We observed a potential gender difference between sleep duration and metabolic syndrome, with an association between metabolic syndrome and long sleep in women and metabolic syndrome and short sleep in men."



Most adults need between seven and nine hours of sleep every night



SCIENCE

Disease-fighting 'warheads' found in bacteria

A recent study by the Scripps Research Institute has unearthed bacteria that produce molecules that can be used to fight antibiotic resistance. Thiocarboxylic acids, a natural by-product of soil-dwelling bacteria, could be a crucial ingredient in antibiotics and heart disease medications.



HISTORY

There's a new way to date ancient skeletons

A new method of dating ancient remains uses DNA mutations from different time periods to estimate the age of bones. Known as Time Population Structure, it was unveiled by the European Society of Human Genetics.



TRANSPORT

Jaguar breaks world record

Zippering across a one-kilometre course on Coniston Water, England, Jaguar's Vector V20E battery-powered speedboat had broken the speed record for a boat of its kind, reaching 142.6 kilometres per hour.

ENVIRONMENT

Volcano song could sound a warning alarm

Monitoring the 'music' of volcanic craters could provide advanced warnings of imminent eruptions

Volcanoes can be both powerful and unpredictable, which makes for a lethal combination. Volcanologists study these mountainous vents to better understand their behaviour and learn how to predict their outbursts. A study published in the American Geophysical Union journal, *Geophysical Research Letters*, explains how researchers have been listening to infrasound recordings from within the Cotopaxi volcano in Ecuador, describing it as the "largest organ pipe" in the world.

"Understanding how each volcano speaks is vital to understanding what's going on," said Jeff Johnson, lead author and volcanologist at Boise State University in Idaho. "Once you realise how a volcano sounds, if there are changes to that sound that leads us to think there are changes going on in the crater, and that causes us to pay attention," he added.

Back in 2015, Cotopaxi blew its top, releasing ash and steam with each eruption and threatening the lives of more than 300,000 people living nearby. As a result, the crater of the volcano changed shape and therefore its sound. As air is forced through the crater it reverberates against the walls to generate a sound that this research describes as a 'voiceprint'. By monitoring changes in a volcano's unique voiceprint scientists may be able to interpret a rumble as a warning sign.

The recent eruptions in Kilauea, Hawaii, have provided further data on volcano sounds. The researchers also stress the importance of understanding the depth of a crater and its interaction with the groundwater, which is believed to have been the cause for the powerful Kilauea eruptions.

The Cotopaxi volcano lay dormant for the majority of the 20th century before erupting several times in August 2015





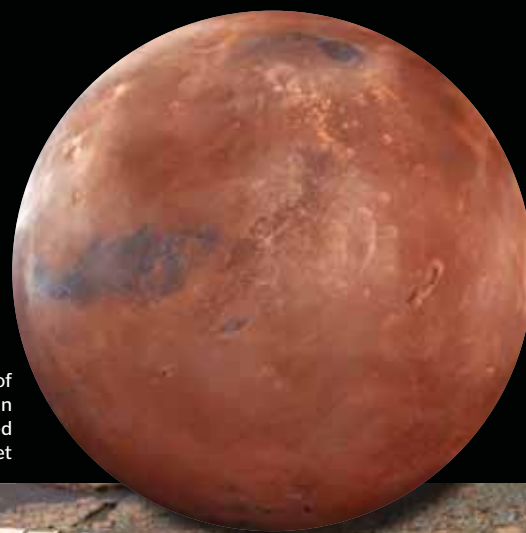
Mars rover battling major dust storm

Opportunity has been put into power-saving mode in the hopes it will survive

The reliable Opportunity Mars rover has braved the surface of the Red Planet for over 14 years, greatly surpassing its original mission duration of just 92 days. However, it now faces a fight for survival in the face of one of the thickest dust storms ever observed on Mars. The storm has completely darkened the planet, depriving the rover of the solar energy it needs in order to operate.

In an attempt to ride out the storm, Opportunity has been put into power-saving sleep mode, and the team at NASA has had limited communication with it over the last few weeks. Even so, they remain confident that while the long-serving rover may face a difficult recovery it should be able to survive this storm.

At the time of writing, the Martian storm has encircled the entire planet



This simulation shows how Opportunity's view has darkened as the storm has intensified



TRANSPORT

Amazon launch new in-car delivery system

The new service means your packages can be delivered directly into your vehicle

Launched in 2017, the Amazon Key service is an innovative delivery solution that allows couriers to unlock your front door and leave your parcel inside. It was a big step from using lockers in stores and building lobbies, but Amazon have since taken the idea one step further. You can now have your parcel delivered to your car by using GPS technology to track your vehicle. Whether your car is parked outside your office or in your driveway, Amazon's delivery drivers will be able to open your boot to leave your parcel inside. The service is currently only available for modern General Motors vehicles that have OnStar enabled or Volvos set up with the On Call service, but it's expected that the system will eventually be rolled out in other cars.

Amazon are the world's third most valuable company



ENVIRONMENT

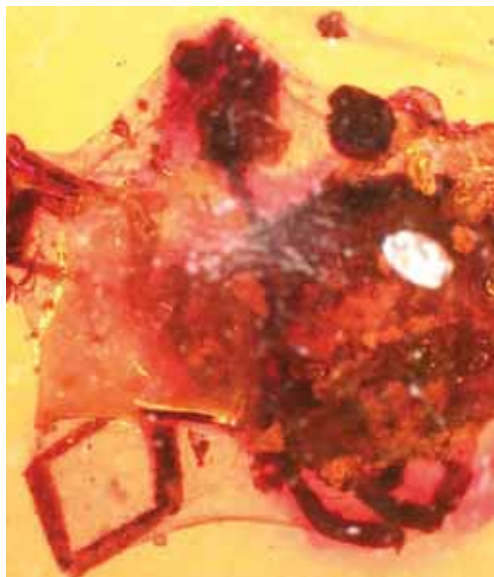
Mass losses of the Antarctic ice sheet

A study from Geodetic Earth System Research at TU Dresden has found that West Antarctica is losing about 160 billion tons of ice every year. The melting of the Antarctic ice sheet has caused the sea level to rise by 7.6 millimetres since 1992.

HISTORY

Tick's tussle trapped in amber

A prehistoric tick's unlucky encounter with a spider has been found trapped in a chunk of amber. Around 99 million years ago the tick was caught and wrapped in silk by the spider, and then it became covered in tree sap.



TECHNOLOGY

'Electronic skin' gives amputees sense of touch

Engineers from Johns Hopkins University, US, have created an e-dermis that provides a real sense of touch when layered on top of prosthetic hands. The e-dermis' sensors act like nerve endings to send impulses to the user's peripheral nerves.

WISH LIST

The latest must-have technology

Tile Sport

■ Price: £30 / \$34.99 / thetileapp.com

We've all found ourselves scratching our heads trying to remember where we put the car keys. With the Tile Sport, you can stop retracing your steps and simply find them with your phone. Essentially a tracking device for your valuables, this pocket-sized tile can be attached to or placed in anything you want to track. It's also waterproof and durable, so it can withstand the hustle and bustle of everyday life. With the accompanying map-style app, users can locate their items provided they are within a 61-metre radius. The Tile will play a loud noise when you're near the misplaced item until it is found. This function works both ways; if you have lost your phone but have your Tile to hand, press the button and it will make your phone ring. With a host of social searching features and smart home device compatibility, the Tile Sport is a must-have when keeping track of your belongings.



Parrot Mambo FPV drone

■ Price: £159.99 / \$179.99 / parrot.com

This tiny drone is small enough to fit in the palm of your hand, but don't let its size fool you – it's very powerful. What sets the FPV apart is its incorporation of First Person View (FPV) technology. The accompanying FreeFlight Mini app connects to the drone's camera, and by putting your smartphone into the provided Parrot Cockpitglasses 2 headset you get a truly immersive FPV experience while flying. The drone's three flying modes mean you can start off at lower speeds until you get the hang of the controls, eventually levelling up to racer mode – saying goodbye to stabilisation systems and hello to high-tech manoeuvrability and incredibly tight turns. The high-performance battery provides up to ten minutes of flight time, and the Parrot Flypad controller lets you fly to a distance of up to 100 metres, which is pretty impressive.



The 3Doodler Create+

■ Price: From \$79.99 / £99.99 / the3doodler.com

The 3Doodler is a 3D printing pen that enables you to create your own freehand designs by drawing into thin air. It's easy to get started; you just load the pen with the colour plastic you want and press the button to start extruding the heated plastic. It hardens almost instantly, so you can take your creations upward out of the page. Each set comes with a choice of different colour plastics, enough to create 190 metres' worth of doodles! If you can't decide on any ideas of your own, don't worry – there are 200 free projects online provided by WobbleWorks Inc that you can practise on. We enjoyed the new features that improve on the original 3Doodler design, particularly the option to alter the speed as you draw and the auto retraction system that prevents oozing.



μHandy Lite

■ Price: £36.95 / \$34.95 / loveuhandy.com

You can now bring the invisible microscopic world around you into view on your smartphone. Whether you're interested in investigating the tiny diatoms growing in a puddle or having a closer look at the petals of your favourite flower, this small and highly portable smartphone microscope is surprisingly powerful. Just clip it onto the lens of your smartphone, download the app and start exploring! We were particularly pleased that we could

ditch cumbersome glass slides and coverslips for μHandy's unique stickers. Gently tap one of the provided stickers onto your sample and it's ready to take a look at. If plant and animal tissue samples aren't your thing, the Sample Cap and Bubble Sampling Sticker lets you observe microscopic aquatic creatures. Collect your stickers in an album so you can revisit them later on.

BB-9E App-Enabled Droid

■ Price: £99.95 / \$149.99 / sphero.com

There's a disturbance in the Force, and it appears to be the BB-9E App-Enabled Droid. Sphero has created the third instalment of its intergalactic robot companions, after R2-D2 and BB-8. The newest addition is full of fine features, including a virtual reality simulation through the app, where you can explore the *Star Wars* galaxy. As a droid of the First Order, this robot is controlled in the same way as its rebellious counterpart BB-8. Once all in the same room, BB-9E can be synced and interact with the other *Star Wars* App-Enabled Droids. Fun for all the family, BB-9E makes a great companion while watching the *Star Wars* saga, reacting as the story unfolds.

WIN!
A SPHERO
BB-9E
SEE PAGE 95
FOR DETAILS



Nanoleaf: Aurora Smarter Kit

■ Price: £179.99 / \$199.99 / nanoleaf.me

This bright gadget really will lighten up your life. By using the accompanying app and display colour wheel, users can set colour schemes to programmable moods. The triangular light panels are interchangeable, so you can create any shape or patterns to fit your living space. Colours are not confined to the individual tiles, however; an array of shades can flow through connecting panels to create an animated light show. It's not just pre-programmed patterns that these panels respond to, but also the sound of music. By using the add-on rhythm module attachment, these lights will flash and fade in response to the tone of a voice or the tempo of a song. The Nanoleaf is an exciting and aesthetic way to brighten up a room and make traditional lighting fun. This piece of interactive art also connects with smart home devices, and the app is available on iOS and Android.



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APPS & GAMES



Space Frontier

■ Developer: Ketchapp
■ Price: Free / App Store / Google Play

Send rockets into space with this addictive launch simulator game. Ok, so it might not be *actual* rocket science, but this game requires precision and timing for the rockets to launch successfully.



Periodic Table

■ Developer: Royal Society of Chemistry
■ Price: Free / App Store / Google Play

If you're studying for a chemistry exam then this app is for you. Jam-packed with information about the world's elements and their everyday uses, this app is the perfect revision tool.



Jurassic World Alive

■ Developer: Ludia Inc
■ Price: Free / App Store / Google Play

It's not strictly educational, but we felt like we were learning a lot as we ran around hunting dinosaurs in this game. Create hybrids, collect species and explore with location-based technology.



Hopscotch: Coding for kids

■ Developer: Hopscotch Technologies
■ Price: £7.99 / \$7.99 monthly / App Store

If you've ever wanted to get into coding, this is the best place to start. You can learn how to create your own apps and games by coding simple instructions in this easy-to-use system, which is designed for ages eight and up.





MEGASHARK



SHARKS

AS ONE OF THE WORLD'S LARGEST PREHISTORIC PREDATORS, THE MIGHTY MEGALODON COULD EAT WHALES FOR BREAKFAST

Words by **Scott Dutfield**

"A megalodon could make the modern-day great white shark its chew toy"

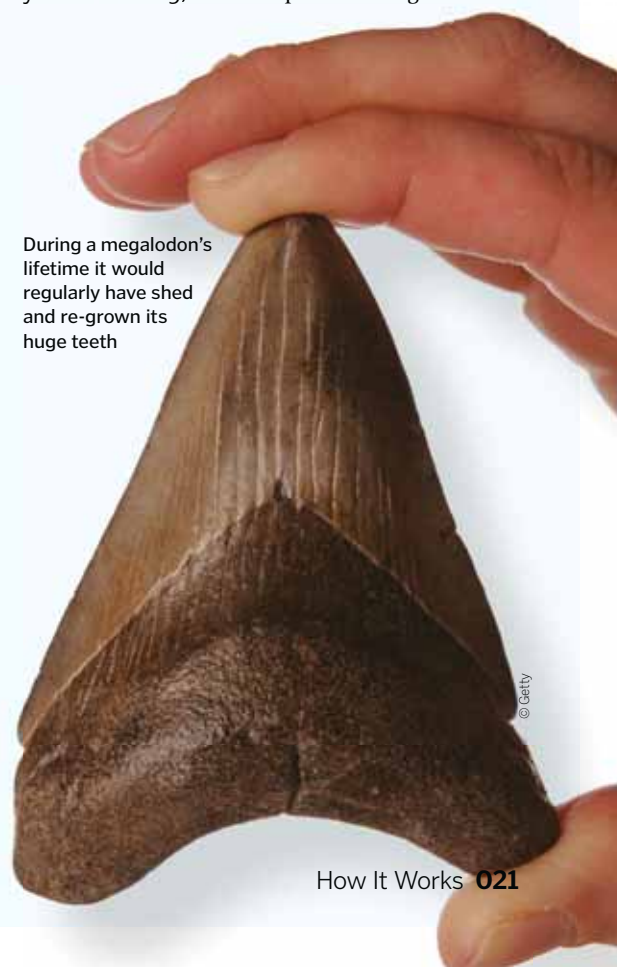
Deep beneath the surface of the Mediterranean, slicing through the open ocean, an iconic silhouette approaches a whale. In a flash it delivers a fatal strike, the whale helpless in the face of nearly 300 serrated teeth as a beast bigger than a bus closes its jaws like a vice. Meeting its end, the whale is but one of the many meals this megalodon will feast upon today. This would have been a regular occurrence around 20 million years ago. Today, whales, along with many other marine mammals, can swim without fear of a giant shark closing in on them with its titanic jaws.

A SHARK'S TALE

A mighty megalodon could make the modern-day great white shark its chew toy. It's estimated that these beasts reached up to 18 metres in length and were armed with around 276 teeth. *Carcharocles megalodon*, as it's formally known, is believed to have navigated the world's oceans during the Neogene period. Megalodon literally translates as 'big tooth', and the species certainly lived up to its name: its teeth could grow up to 18 centimetres and were arranged in five separate rows. This, along with its sheer mass and bite force, made it the most deadly predator known to ever swim the seas.

Its prestigious predatory status has made the megalodon a prehistoric sea monster that is frequently showcased in feature films, where it faces off against other gargantuan beasts. These fearsome fish will grace the big screen again this year in *The Meg*, which depicts the megalodon as

During a megalodon's lifetime it would regularly have shed and re-grown its huge teeth





a giant killing machine hell-bent on hunting down unsuspecting swimmers. In reality, the megalodon would have had bigger fish to fry than comparatively tiny humans. A megalodon would need to consume around a ton of food per day to maintain its 60-plus-ton weight, and on its mega menu were whales, seals and fish – including other sharks. And like other shark species, megalodons didn't just feast on freshly caught prey; they were also scavengers. If the remains of another creature's kill floated by, the megalodon was not one to turn its nose up at a free meal.

The Mediterranean Sea wasn't the only hunting region for these mega sharks; evidence of their predatory presence has been found across the globe's warmer waters. From the coasts of North and South America to the far reaches of the Indian Ocean, during the megalodons' prime it dominated intercontinental waters as an apex predator.

Back in 2010, a team of palaeontologists discovered a 10-million-year-old prehistoric shark nursery in Panama. Over 400 fossilised megalodon teeth were recovered, with most ranging between 1.6 to 7.2 centimetres in length. From these teeth the researchers estimated that the young megalodons would have been between two and 10.5 metres long.

SHARK-TOOTHED COUSINS

It's often said that modern-day great white sharks are smaller 'living fossils' of the once magnificent megalodon. Unfortunately, the palaeontologists trying to understand the truth about the great white's heritage have limited resources available to them.

The fossilised dental records of these mega sharks are scattered across the world, each fragment of tooth an indicator of a shark's size, shape, diet and ancestry. Like modern-day sharks, a megalodon's body was predominately made up of cartilage. Unlike bone, cartilage is



Today, the great white shark is the largest predatory fish on Earth

rarely preserved in sediment over millennia, so we don't find whole fossilised sharks in the same way we do dinosaurs. However, their centra (the main body of the vertebrae) can sometimes become calcified and preserved, leaving behind what look like rocky hockey pucks. In a similar way as counting the rings of a tree, the layers in these centra can reveal the age of a megalodon at death. The biological biography formed from these tooth and spine samples allows palaeontologists to answer a question long debated in the scientific community: is the modern-day great white shark a direct descendant of the megalodon?

It was previously believed that from mega sharks came the great white, a conclusion based on their dental duality. However, in recent years some palaeontologists have proposed another theory: that great whites descend from an ancient mako shark, and the two evolved side by side. The megalodon itself descended from enormous prehistoric sharks such as the otodus,

a near ten-metre-long fish that dominated the oceans 50 million years ago. Both great whites and megalodons do share common ancestry, originating from a group of fish called Lamniformes, or mackerel sharks, as they are also commonly known. As the first shark-like creatures, Lamniformes began their evolutionary journey around 65 million years ago, diversifying and developing along the way into the sharp-toothed species we see today.

THE MEGA EXTINCTION

As invincible as they may appear at the box office, the megalodon could not fight off the forces of mother nature. The demise of these behemoths around 2.6 million years ago is believed to have been the result of several contributing factors.

As climatic temperatures became cooler, megalodons moved to warmer waters to hunt and reproduce. However, their prey species – such as primitive baleen whales – were moving

Shark family line

Meet some of the megalodon's prehistoric relatives



390 MYA

Stethacanthus

Sometimes known as the 'ironing board shark', it's still relatively unclear why this fish had such an unusual protrusion, though it has been suggested it was used during mating.

350 MYA

Falcatus

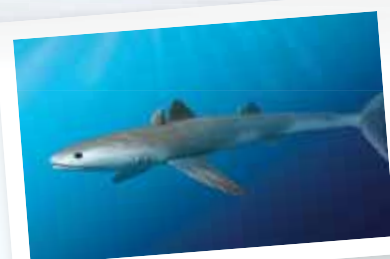
Found around the shallow waters of what is now North America, these sharks fed on smaller aquatic animals.



370 MYA

Cladoseleche

Unlike the sharks of today, these prehistoric predators had smooth teeth rather than sharp ones, suggesting they swallowed their prey whole.



270 MYA

Helicoprion & edestus

away from tropical waters, thereby reducing the availability of food. It has also been suggested that megalodons faced competition from the ancient ancestors of the killer whale, which were able to sustain themselves on smaller prey due to their smaller size. As mammals, these whales were also able to store fat and energy in blubber, giving them an extra advantage. As competition for food from growing whale populations increased, megalodons may have simply starved to death.

Although the megalodon may have been wiped from the face of the planet, our fascination with this ferocious fish has not gone extinct. There are those who believe this beast is still

lurking in the ocean depths, and some have even claimed to have spotted them. In his 1963 book, *Sharks and Rays of Australian Seas*, Australian naturalist David Stead relayed a tale from a group of fishermen who in 1918 claimed to have seen a gigantic shark that could only be compared to a megalodon. However, this claim, along with the many others that followed, remains unproven.

The story of a living megalodon remains a fishy fairy tale. Even so, our oceans are still vastly unexplored, with 95 per cent yet to be studied. Maybe somewhere in the depths of one of the world's oceans there really is a whale about to meet its maker at the jaws of this mega-predator.

"Stories of a living megalodon remain a fishy fairy tale"

Bizarre bites

The megalodon was just one of many prehistoric predators whose appearance was more like something from science fiction than reality. The evolution of marine species over time has produced some truly weird and wonderful predators. The helicoprion ('spiral tooth') and edestus ('scissor tooth'), for example, were a pair of fish that really diversified the aesthetics of marine predators with their bizarre arrangements of teeth.

The helicoprion presented its teeth as a central arch in its lower jaw, whereas the mouth of the edestus housed two rows of centralised interlocking teeth. Cruising through the ancient oceans 270 million years ago, this dangerous duo weren't strictly sharks – both instead classified as chimaeras, or ratfish – although they do bear a striking resemblance.



The helicoprion's 'whorl' (or spiral) of teeth allowed it to cut through soft prey such as squid



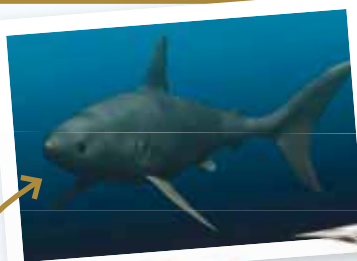
The edestus' teeth could slice through its prey as easily as scissors cut through paper

259 MYA Hybodus

Around 2m long, these prehistoric sharks developed the more solid internal cartilage structure we see in modern-day sharks.

60 MYA Otodus

The dawn of the giant sharks began with the otodus, a fish estimated to have been around 9m long and one that ate prehistoric whales.



100 MYA Cretoxyrhina

Also known as 'Cretaceous jaws', these sharks tackled marine dinosaurs as well as other fish for their meals.



23 MYA Megalodon

SHARKS ON THE BIG SCREEN

Jaws 1975

It might not be a megalodon that swims centre stage in this iconic film, but the infamous great white certainly strikes fear into the hearts of the residents of Amity Island in Steven Spielberg's classic.



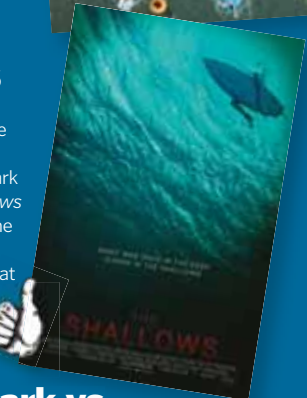
The Meg 2018

Though this megalodon film isn't out yet, the trailer suggests it will be an action-packed and dramatic story. From what we can gauge, the prehistoric predator will be munching through plenty of swimmers.



The Shallows 2016

Arguably one of the most intense and suspense-filled shark movies, *The Shallows* superbly depicts the sheer predatory prowess of the great white. An aptly named seagull is another bonus.



Mega Shark vs Crocosaurus 2010

One of the many films that pits a megalodon against another titanic beast (in this instance a 46m-long crocodile) this preposterous instalment reveals the havoc that a battle between the two ridiculously massive monsters would cause.



Sand Sharks 2011

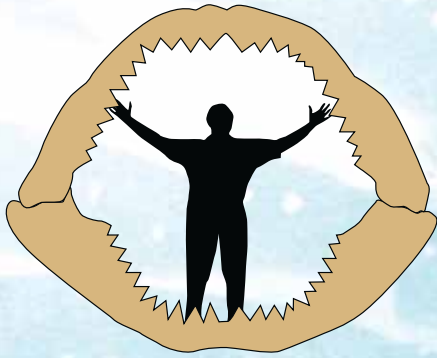
Excellent as a piece of unintentional comedy, this film shows sharks as they have never been seen before, cruising through sand (yes, sand) before devouring an unsuspecting beachgoer in one huge gulp.





THE TOOLS OF A TITAN

Discover what placed the ferocious megalodon at the top of the food chain



Jaws

In order to feast on the flesh of marine giants, the megalodon's open jaws spanned around 3m by 2.5m – easily big enough to have swallowed a human whole.

Speed

With its powerful tail, a megalodon could reach a top speed of 5m/s.

The megalodon hunted several ocean species, including the now extinct dwarf whale, which was similar in size to a minke whale (pictured below)



Distribution

With this monster terrorising the seas, nowhere was safe



63.5tn

The estimated weight of an average megalodon

Scales

The enormous body of the megalodon is thought to have been covered in dense layers of hard, scale-like armour typical of shark species.

Gills

In the same way sharks today exchange oxygen and carbon dioxide, the megalodon is thought to have had to move constantly to ensure water passed through its gills.

Inside the gills of a giant

It is likely that the megalodon had gills similar to those of modern-day sharks

Water

In order to obtain oxygen for respiration, some species, including the great white, continually swim to force water through their gills, known as ram ventilation.

Gill filaments

These slits are where respiration takes place, but also offer protection against any dirt or debris entering the gills.

Capillaries

This is where gas exchange takes place. Oxygen is absorbed from the passing water into the shark's bloodstream.

Heart

The two-chambered heart directs deoxygenated blood towards the gills, while oxygenated blood is sent around the rest of the body.

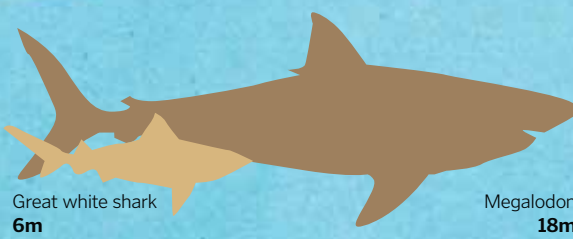
"Young megalodons would have been between two and 10.5 metres long"

Teeth

The largest known shark teeth that ever existed, each of the megalodon's 200-plus teeth were serrated to cut through its prey.

The megalodon exerted a bite force of up to

18,600kg



Great white shark
6m

Megalodon
18m



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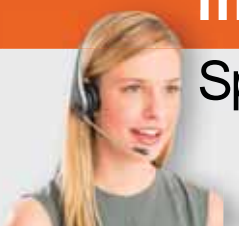
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Prehistoric wildlife

This fossil proved that life existed around 560 million years ago

5 45 million years ago there was no life on land, but the oceans were teeming with it. So many fossil finds date to this point in history – the Cambrian period – that scientists believed no organisms existed earlier. This theory was disproved in 1957 after a schoolboy made a startling discovery.

Roger Mason came across a leaf-like fossil in Charnwood Forest, UK, a species that became known as *Charnia masoni*. The fossil was found within rocks that were pre-Cambrian, proving that life was far more ancient than previously thought. Decades earlier, Charles Darwin had predicted that life existed before the Cambrian age – finally here was the proof.

Charnia is believed to have been rooted to the ocean floor, feeding on microbes in the water. It had a quilted body that some experts believe may have stored algae, giving it a green colour that enabled it to gather energy from sunlight through photosynthesis.

Fossils from other pre-Cambrian creatures are rare as their squishy bodies could only fossilise under precise conditions. Some of these ocean dwellers evolved shells and skeletons during the Cambrian era, which explains the abundance of fossils and the long-held idea of an explosion of life at this time.

Charnia lived on the seafloor, perhaps feeding on microbes



Fossils of *Charnia* have been found all around the world

© Getty, Wiki/Matteo De Stefano, MUSE. Illustration by The Art Agency/Peter Scott

The Doomsday Clock

Why is it two minutes to midnight and what does that mean?

The Doomsday Clock was created by the *Bulletin of the Atomic Scientists* (BAS) in 1947 to symbolise the urgency of a nuclear threat. The hands of a clock ticking down to midnight were shown on the magazine's cover, like the countdown of an atomic bomb. It was the idea of a group of scientists who had participated in the Manhattan Project – an American-led scheme to develop the first nuclear weapons during World War Two.

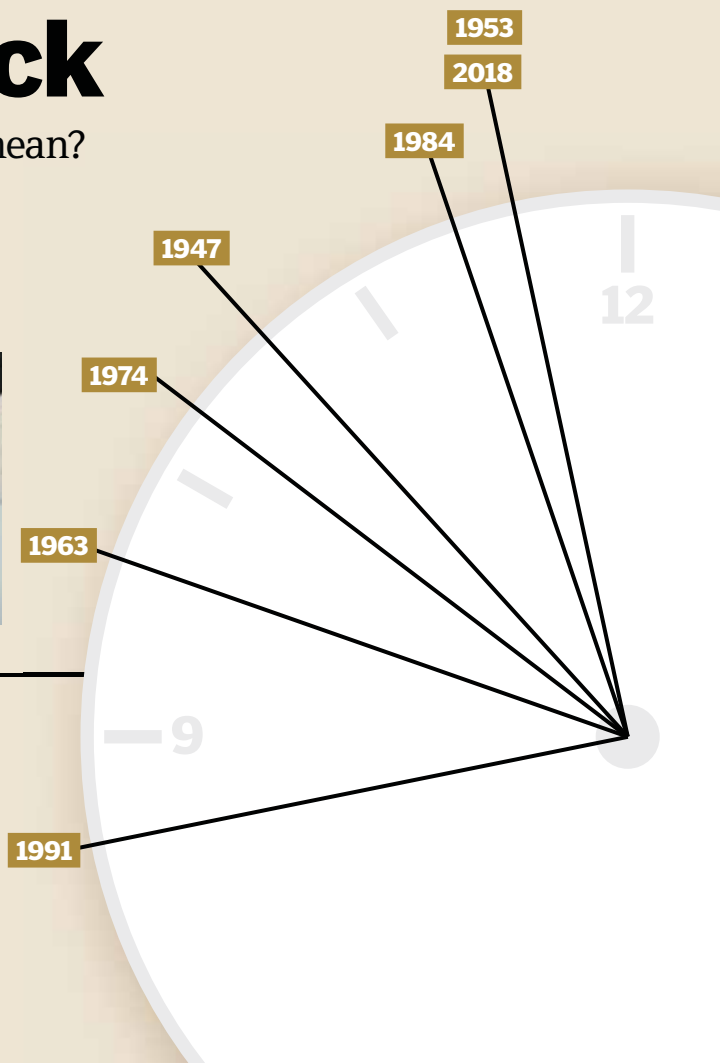
Since then, the Doomsday Clock has continually been updated, but it now

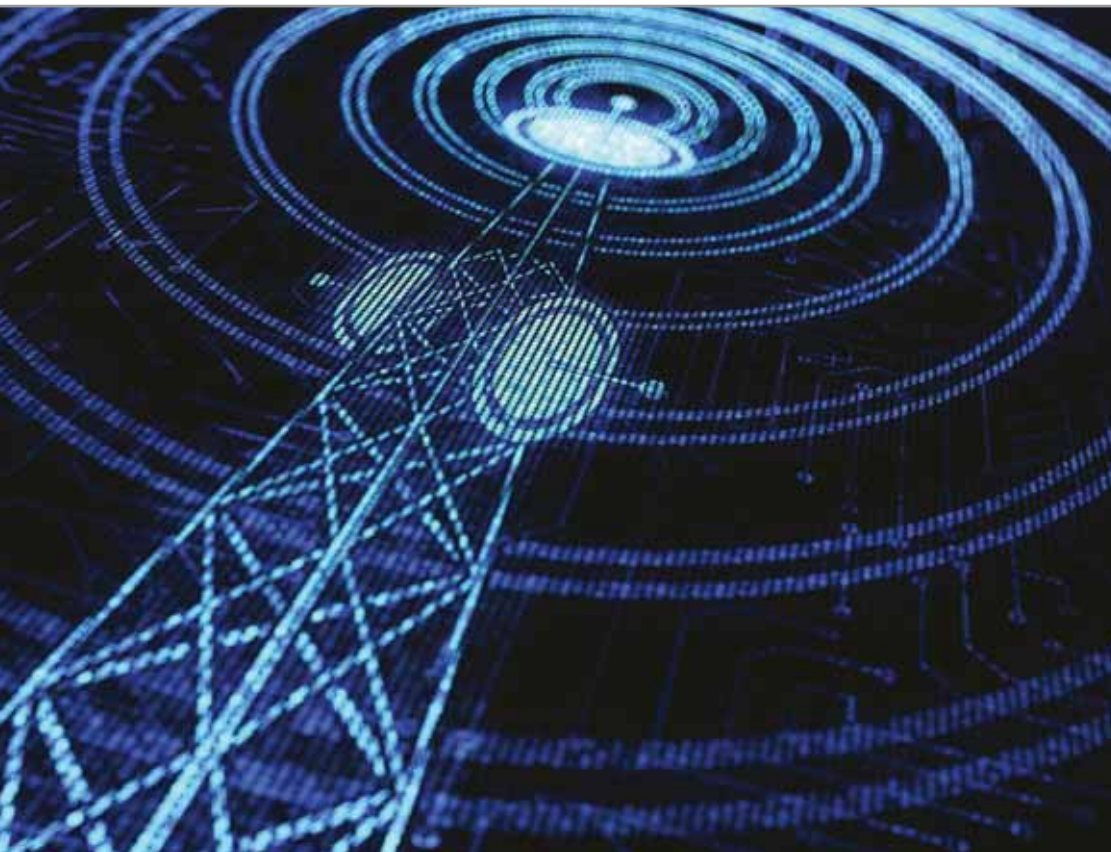
alerts the public to other dangers such as climate change and cyber warfare. It is now just two minutes to midnight and nuclear threats have taken centre stage once again.

Physicist Dr Leon Lederman adjusts the hands of the Doomsday Clock in 2002



| 1947 | 1953 | 1963 | 1974 | 1984 | 1991 | 2018 |
|------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------|
| The Doomsday Clock appears for the first time, triggered by Cold War tensions and the threat of nuclear dangers. | The United States and Soviet Union test hydrogen bombs, weapons more powerful than any atomic bombs. | The Partial Test Ban Treaty is signed and ends all atmospheric nuclear testing, slowing the arms race. | The US and Soviet Union appear to be modernising their nuclear forces, while other nations increase their nuclear capabilities. | There are worries that a new arms race will begin after relations between the US and the Soviet Union break down. | With the Cold War officially over, the Strategic Arms Reduction Treaty reduces the number of US and Russian nuclear weapons. | The threat of nuclear war, rising tensions between nations and climate change push the clock closer to midnight. |





Russia's ghost radio station

A mysterious shortwave signal is broadcasting an eerie buzz, but nobody knows why

A short, monotonous buzz being broadcast 24 hours a day is currently being emitted from a radio station at an unknown location in Russia. The mysterious sound repeats at a rate of 25 times a minute, broken only by the occasional live Russian voice transmission. Is the signal used for military communications, perhaps just a channel marker to keep the frequency busy so it is easier to use? Or is the sound the result of something more sinister? The earliest known recording has been dated to 1982, and many theories have been proposed since then.

Its original call sign was UVB-76, but today the tower uses ZhUOZ. The buzz is broken by Russian words, but they offer no real clue as to the function of the radio or its origins. They are often common nouns, including 'virus' and 'prison'. It sounds like a

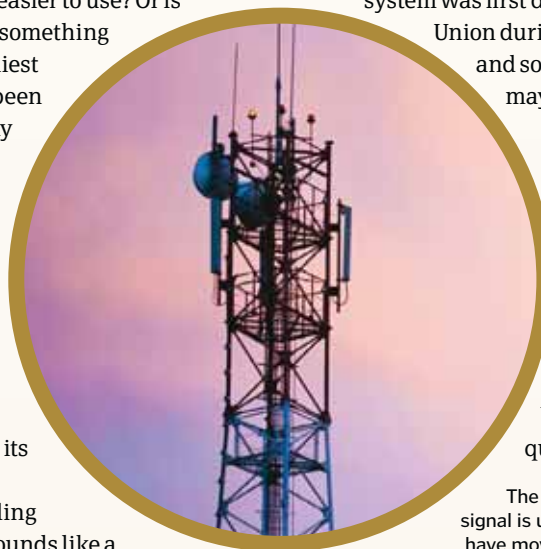
code, but the Russian military claim they have nothing to do with the mysterious signal.

Perhaps the most chilling theory is that the tone might be what is known as a 'Dead Hand' signal, a system designed to automatically retaliate with deadly nuclear strikes in response to a nuclear attack on Russia, which would be picked up by radio wave interference. This

system was first devised by the Soviet Union during the Cold War era, and some experts suggest it may still be in use today.

Regardless of its origins, there must be someone behind the signal and there must be someone tuning into the live transmission who knows the real reason why the broadcast is being sent out. The question is who?

The exact source location of the signal is unknown, and it's thought to have moved on at least one occasion

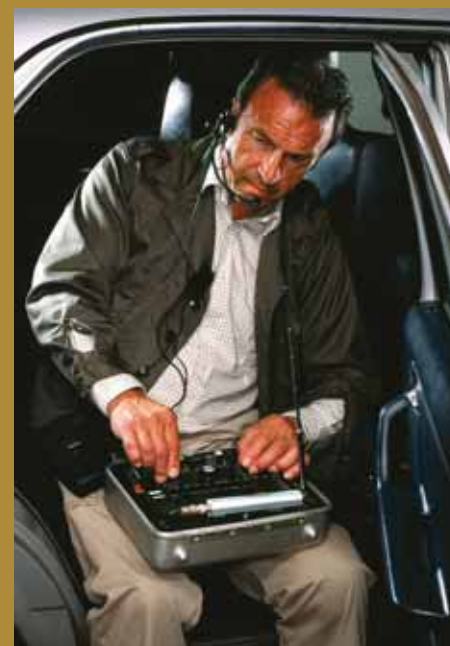


Clues from the buzzer

The only clues about the purpose of this tower come from the sound of the signal itself. We know that the buzz continues 24 hours a day, seven days a week, 365 days a year, and it has done so for at least three decades. During this time the sound has altered occasionally and sometimes even paused for brief periods, but it has never fully stopped.

We know that UVB-76 became more vocal after the fall of communism in Russia – which may give a hint of a political identity – and after the turn of the millennium even more communications were heard over the frequency. With the increase in global interest from radio enthusiasts, it has become evident the sound isn't recorded. Instead, it is being created manually by a tonewheel and picked up by a microphone. If you listen long enough to the broadcast you can very occasionally hear muffled conversations or sounds of things moving in the background.

Other notable events include approximately 24 hours of eerie silence on 5 June 2010, and in September 2010 the station was moved and began to use a new call sign – MDZhB. On 11 November 2010, a conversation involving 'bridge operative officer on duty' was broadcast – it's suspected that this was accidental.



A similarly strange radio signal, broadcast from Cyprus between the 1970s and 2008, is believed to have been operated by the British Secret Intelligence Service



Le Mont Saint-Michel

This medieval monastery is a fortified marvel and one of France's most iconic historic sites

The island of Mont Saint-Michel has survived sieges, fires and revolutions over the centuries. While it was once the destination of thousands of travelling pilgrims, today, it is a tourist hotspot and a World Heritage site.

Located at the mouth of the river Couesnon, the mount was originally entirely cut off from the mainland at high tide. This provided a natural defence against enemies, as even at low tide the exposed sand flats were treacherous to cross. The Bayeux Tapestry even depicts William the Conqueror's knights falling into the surrounding quicksand. During the 19th century a causeway was built, providing a safer link to the mainland at low tide. In 2014, a permanent two-kilometre-long bridge replaced this, enabling tourists to travel across safely.

The island's fortifications were constructed during the 14th and 15th centuries to defend against English armies during the Hundred Years' War. Cannons abandoned by a besieging English general in 1434 are still on display at the gates. Behind the walls, the village of Mont Saint-Michel stretches around the base of the mount, with winding roads leading to the entrance of the abbey.

Many experts have observed how this layout reflects the hierarchy of medieval society, with the church at the peak of the mount, towering above the shops and houses below. However, after the French Revolution the island was claimed by the new government and converted into a prison. Today, Mont Saint-Michel is still a functioning monastery, and a marvel for visitors.

"Even at low tide the exposed sand flats were treacherous to cross"

The abbey of Mont Saint-Michel was built 80 metres above sea level





The Bayeux Tapestry depicts Mont Saint-Michel and William the Conqueror's knights caught in the surrounding quicksand

5 FACTS ABOUT MONT SAINT-MICHEL

- 1 An English twin**
Located in Penzance, Cornwall, St Michael's Mount was its English counterpart – the oldest buildings there date back to the 12th century.
- 2 Tourist boom**
Around 2.5 million people visit the island every year, making tourism the town's primary source of income.
- 3 Tiny population**
In 2015 the island was home to just 33 people, including several monks and nuns who live in the abbey quarters.
- 4 Medieval mount**
The site is over 1,300 years old, with the first chapel constructed in 708 CE and dedicated to the Archangel Michael.
- 5 Tidal power**
Mont Saint-Michel Bay experiences some of the highest tides in continental Europe. There can be a difference of up to 15 metres between low and high tide.





ARE WE STILL EVOLVING

Have culture and technology stopped evolution in its tracks?

Words by **Laura Mears**



NG?



"The genetic differences between us are surprisingly small"

Every human alive today can trace their ancestry back to east Africa around 200,000 years ago – DNA from a single woman still exists in every one of our cells. At the time, the human population was tiny, and her descendants are the only ones still alive today. They spread across the continent 100,000 years ago before radiating out in waves across the world. Scientists know the mother of humanity as mitochondrial Eve.

We may have dispersed, but the genetic differences between us are surprisingly small. There is no major distinction between people living on different continents or people of different races. In fact, there are more genetic differences between subspecies of chimpanzee. This similarity makes people question whether we've stopped evolving completely.

Evolution relies on a few key ingredients. Every generation, an organism makes more individuals than are able to survive. There are differences between those individuals, known as phenotypic variation. The cause of those differences, genes or genotype, are heritable, meaning that they can pass from one generation to the next. Some traits are better suited to the current environment than others. Individuals with those traits are more likely to survive and reproduce, passing the genes for their traits on to the next generation.

New traits enter populations in three main ways, the most well-known of which is mutation. When we make sperm or eggs, cells in our reproductive organs copy their DNA. This process is error-prone, so every time it happens mistakes creep in. This creates tiny changes in the genetic code that pass to the next generation. For the most part the differences don't do anything useful – or harmful. The mutations are often silent (they do nothing) or neutral (they do something, but it doesn't make a difference). In fact, many mutations aren't even in genes;

© Getty



Modern medicine reduces the pressure of illness on our species



they're in the DNA that sits between them. However, sometimes mutations change the way a gene works.

New traits can also enter populations via gene flow. This happens when groups of people separate and then come back together, sharing new genetic information. Finally, traits change because of sex. Babies inherit genetic material from both parents, putting new combinations of genes together.

Over the past 100,000 years these three mechanisms have changed the traits that make us human, but we are still young in evolutionary terms. We take a long time to reproduce, and there's a limit to the amount of variation that can accumulate in a few hundred thousand years. Your genetic information only differs from mine by around 0.1 per cent, and most of those differences are single letter changes. Despite outward appearances, the whole human population still shares close family ties.

Our genes are always changing, but genetics is just one piece of the evolutionary puzzle. Our environment has a huge role to play in how our species evolves. For new traits to pass from generation to generation they need to change our chances of survival. This is where Darwin's

natural selection comes in. If a genetic change makes an individual more likely to reproduce they have a better chance of passing on their genes. We know this as 'survival of the fittest', but it's not always about being the biggest, strongest or fastest. It's about having traits that let you make the best use of your current environment. As the environment changes, so do the kind of mutations that might be useful.

This is where human evolution gets complicated. We can change our environment with culture, science and technology, messing with natural selection. If you look deep into history, our human-like ancestors were at the mercy of their environment. Lucy, a famous fossil of a species known as *Australopithecus afarensis*, lived 3.2 million years ago. She had ape-like characteristics, including a large jaw, long arms and a covering of fur, but she walked on two legs. She lived in the trees like other apes, but the environment was changing, trees were disappearing, and Lucy was spending more time on the ground. Eggs found near her remains suggest she might have been foraging.

Between Lucy and mitochondrial Eve, climate change eventually forced our ancestors out of the forests and onto the plains. They had to run



Agriculture gave us stable access to food, freeing up time for science

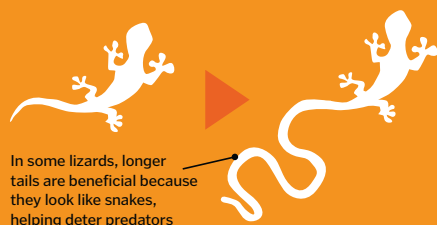
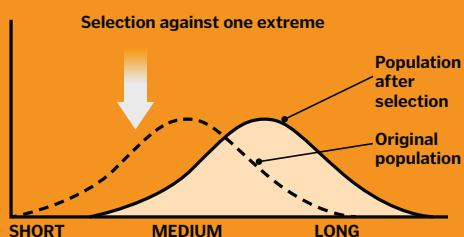
"Your genetic information only differs from mine by around 0.1 per cent"

Types of selection

Three laws of natural selection govern evolution, but other selective factors can play a role

Directional

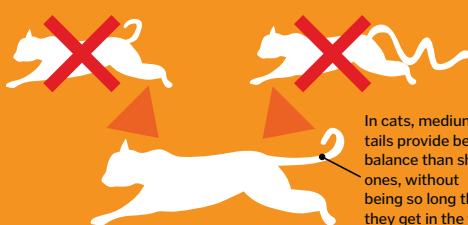
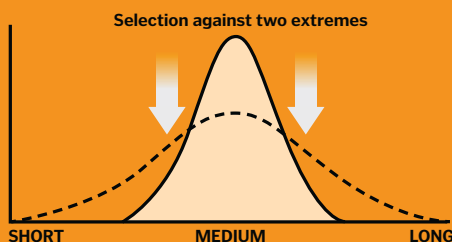
If the environment changes, it forces organisms to adapt. Directional selection pushes traits in one direction, towards a new solution. Once they find the solution, traits can stabilise again, unless the environment keeps shifting.



In some lizards, longer tails are beneficial because they look like snakes, helping deter predators

Stabilising

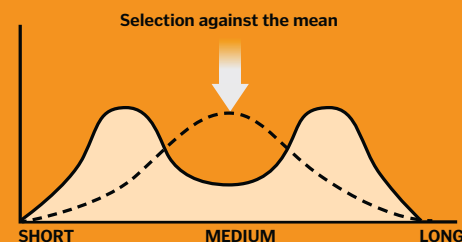
Stabilising selection encourages organisms to keep the same traits. This tends to happen when the environment is stable and the organism is already well adapted. Any changes make them less fit and therefore less likely to pass on their genes.



In cats, medium tails provide better balance than short ones, without being so long that they get in the way

Disruptive

Sometimes there is more than one way to adapt to a change in the environment. In these situations organisms evolve away from the middle ground and towards one of two extremes. If this persists a population may split into two new species.



Short tails help ground squirrels avoid getting caught by predators

Long tails help tree squirrels balance

Medium tails provide no particular benefit

Sexual

Natural selection favours animals best suited to their environment, but it's not the only way. Sexual selection favours traits that make individuals more attractive and more likely to reproduce, even if they don't help them to survive.



Artificial

Artificial selection works in the same way as natural selection, except that we make the decisions. By choosing which animals to breed, we dictate which traits are passed on to the next generation.

Evolutionary leftovers

Humans still carry some of the adaptations of our ancestors

Ear muscles

The three auricular muscles around the ears help cats and dogs to point their ears in the direction of noises. Some people can wiggle them, but they aren't much use to us.



Vomeronasal organ

This pheromone-sensing organ helps many animals to communicate using chemical signals. Most adults seem to have one, but whether it still actually works is unknown.



Wisdom teeth

Four extra molars may have been useful to our ancestors, who had larger mouths and tougher diets, but we don't really need them any more. Some people don't have any.



Arm muscles

The palmaris longus muscles help primates to swing from trees, but we no longer need them. Most people still have short tendons, but in some people they are missing.



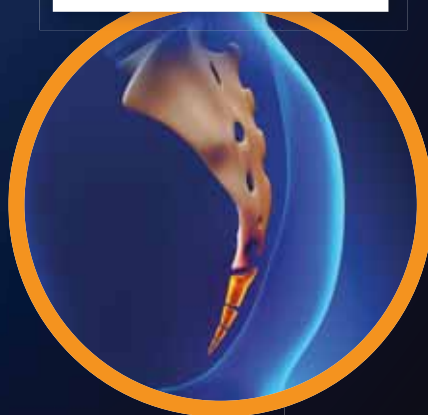
Appendix

Although we don't need an appendix to survive, it may not be completely useless. It's still thought to play a role in maintaining healthy gut bacteria.



Coccyx

Developing human embryos form a tail in the womb, but it quickly disappears again, leaving behind a short 'tailbone' called the coccyx.





under blazing sunshine to survive, and body hair became a burden. Bare skin and the ability to lose heat by sweating became an advantage. Pressure from the environment pushed the genes of our ancestors to change.

Over time, early humans evolved bigger brains, smaller jaws and complex social structures. We harnessed fire and invented tools, and as we became more intelligent we made more and more changes to our environment. This changed everything.

The advent of agriculture around 10,000 years ago caused a seismic shift in human history. Suddenly, we could produce our own food on demand, right next to our homes. DNA from ancient humans has revealed that changing our

own environment changed at least 12 regions of our genetic code.

Researchers at Harvard Medical School examined the remains of 230 people who lived between 8,500 and 2,300 years ago. They found differences in genes involved in height, metabolism and skin pigmentation. Around 4,000 years ago, a mutation appeared that allowed adults to keep digesting milk. Light skin became more common, which the researchers believe may have been a response to less vitamin D in a plant-based farmer's diet. The immune system also changed, which may have helped people to live closer together.

We share behaviours that we learn during our lifetimes, passing information from generation to generation like genes. Learning and culture change our environment, changing the pressures that drive selection. This kind of genetic and cultural co-evolution isn't unique to humans. Whales and dolphins are some of the most intelligent animals on the planet, and there is evidence that they also evolve in response to learning.

Killer whales can tackle many different types of prey, but certain groups prefer different meals. In the North Atlantic, for example, some like salmon, some prefer mammals, and others eat sharks. These cultural preferences pass from mother to baby, and because the groups don't tend to mix, they stay the same across generations. Scientists found differences in the

genetics of whales that eat fish versus those that eat mammals. We changed our genes by learning to farm, and they've changed theirs by choosing which prey to eat.

This cultural learning helps us to keep adapting, but humans have taken it further than any other animal. We made clothes and complex shelters. We domesticated plants and animals to provide a steady source of food. We built boats, cars and planes to explore the world. We invented medicine to treat injuries and disease. We made it possible to choose when – and if – to have children. We can even survive in space. We have secured our environment, reducing the pressures that push other species to change over time. Reducing those pressures freed up even more time for new ideas and new technologies. Science has made it possible to change our environment more than ever before, but does that mean that we've stopped evolving?

It's hard to see evolution in action in human populations today because we have such a long lifespan, and even when natural selection isn't happening, our genes continue to mutate, a phenomenon known as genetic drift. However, there is one serious selective pressure that we still don't have under control: disease. If you look into its past you can see how modern humans have changed in recent years.

The plague ripped through Europe around 750 years ago, killing vast numbers of people. When our species faces diseases we can't yet treat,

Ongoing evolution

Two recent studies have found evidence to suggest that we are indeed still evolving, albeit very slowly. Among smokers, those with a variant of a gene known as *CHRNA3* are associated with smoking more heavily than average. Being a heavy smoker increases the risk of dying from a smoking-related disease, such as lung cancer. Scientists found that, between generations of 80-year-olds and 60-year-olds, the variant of this gene has decreased by about one per cent. However, until further data is collected from younger generations, this trend cannot be confirmed.

A similar decline seems to be emerging in those with a variant of the gene *ApoE4*, which increases the risk of developing late-onset Alzheimer's and cardiovascular disease. One possible explanation for both these gene variants becoming rarer is that more people are having children later. The number of people waiting until their 40s or 50s to start a family is increasing, but this is also the age at which people with such gene variants may be at risk of dying.



Smokers with a variation in the *CHRNA3* gene are more likely to be heavy smokers



The jaws of humans and chimpanzees reflect our different diets



The development of technology will continue to shape the future of our species



Changes to our genes are only part of our evolutionary story

"Cultural learning helps us to keep adapting"

natural selection takes over. Scientists think that's why modern populations in Northern Europe have a higher frequency of a mutation in a gene called CCR5. This gene codes for a molecule used by the immune system, and it provides protection against the plague bacteria, *Yersinia pestis*. It also protects against the HIV virus. People with the protective trait were more likely to survive, and their descendants are still alive today.

As a species we have outsourced huge parts of our survival to technology. We control our environment to maintain a steady state, reducing the pressure that forces genes to change, but to keep this going we need our environment to stay the same, and we haven't worked it all out yet.

What happens when the climate changes, or when antibiotics no longer work as they should? We have buffered ourselves against natural selection for the moment, but we haven't out-evolved evolution.

Future humans

Work is underway to extend our understanding of evolution beyond the ideas set out by Darwin. It's not just genetic inheritance that affects our evolution; the environment that our parents pass on changes us too. In new environments different genes become more or less useful to our survival. By changing our environment we change the selective pressures that drive our species forward. In biology this process is known as niche construction.

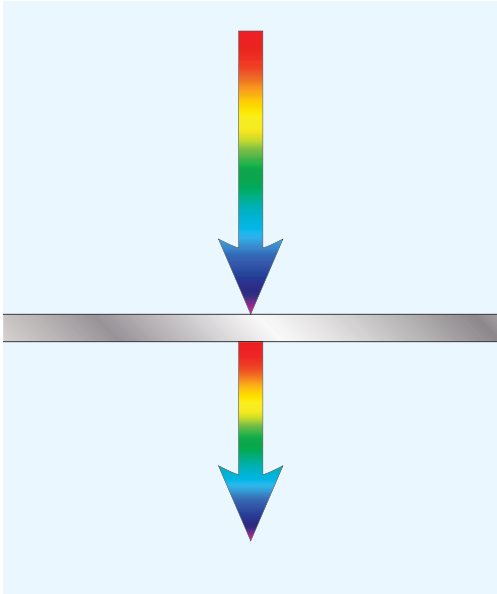
Data suggests that cultural evolution has already changed the way that our genes evolved by affecting the type of selection we are under. Even so, our genes don't always need to change for our species to adapt. We can change our environment much more rapidly than we change our genes, allowing us to thrive in situations that our biology couldn't handle alone. Computer simulations suggest that this kind of cultural evolution could work in a similar way to genetic evolution, only faster. Who knows where that will take us as human culture continues to change and technology continues to improve.



Water droplets refract red light by 42° and blue by 40° , splitting the spectrum into a rainbow

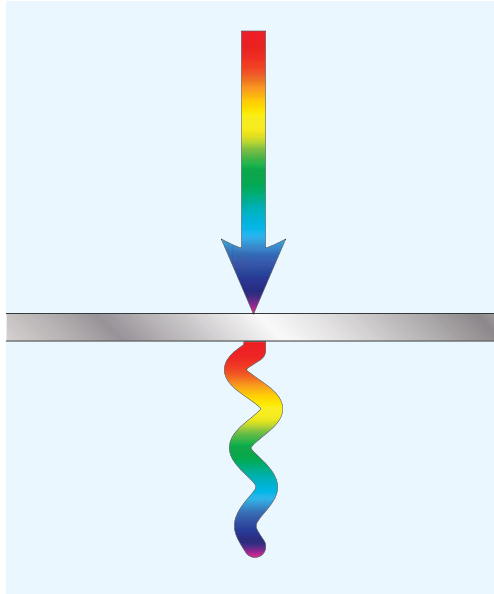
How light behaves

Wavelength and frequency affect the way light interacts with different materials



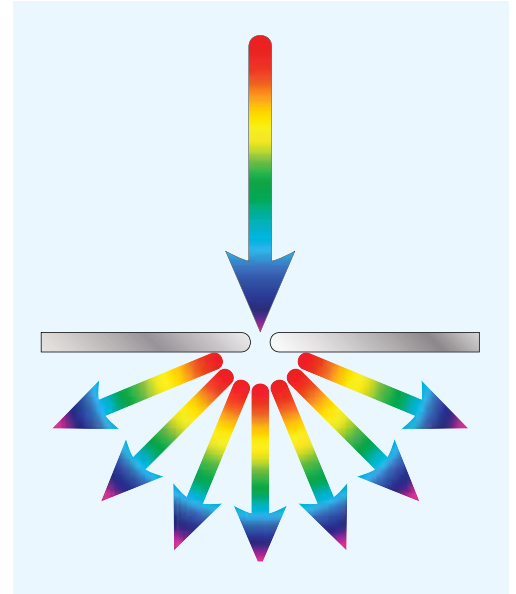
Transmission

Transparent objects allow light to pass straight through without absorbing much of its energy. When light hits the object's electrons, they vibrate a little before re-emitting the light in the same direction. The energy passes from atom to atom and out through the other side.



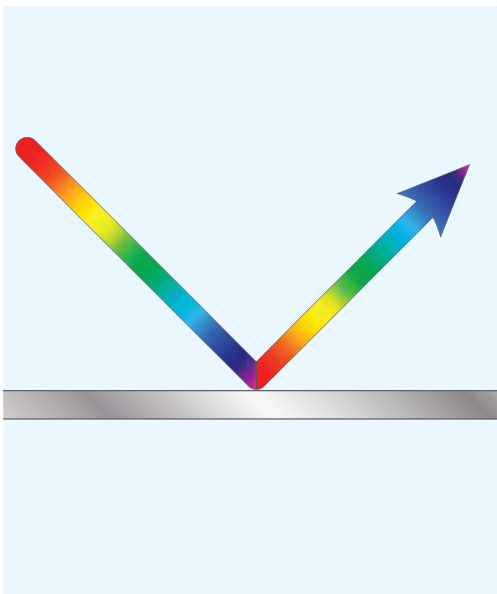
Absorption

Opaque objects absorb light, converting its energy into heat. This happens when the frequency of light matches the frequency of the vibrations of the object's electrons. Colourful objects absorb some wavelengths and reflect others, changing the composition of the light that we see.



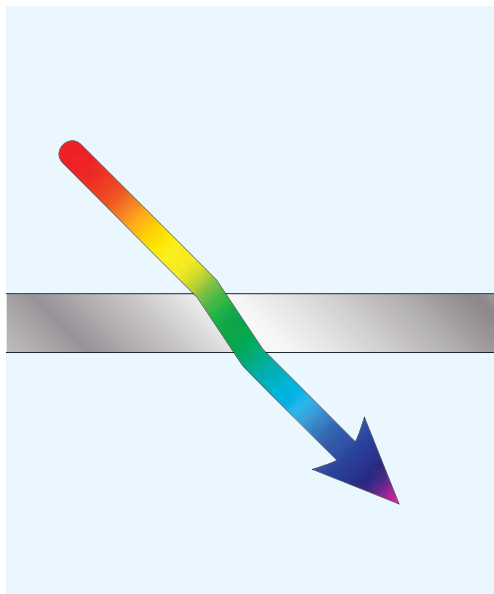
Diffraction

When light passes through a gap smaller than its wavelength or passes a particle of a similar size, it diffracts. As the waves pass through the gap they bend and spread out. The smaller the gap compared to the size of the wavelength, the more the light diffracts.



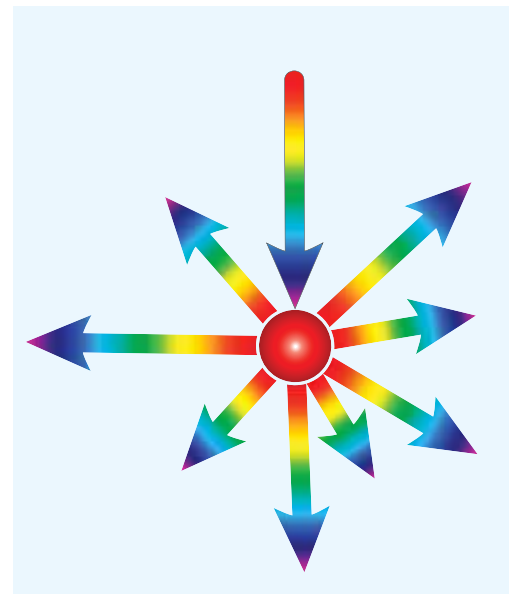
Reflection

Reflective objects bounce light back. When light hits, the electrons vibrate but they don't absorb the energy. Instead, they send the light out towards neighbouring atoms. The angle of reflection is equal to the angle at which the light hits the object, which is known as the angle of incidence.



Refraction

If light passes from one material to another at an angle of 90° degrees, nothing special happens. However, if the materials have different densities and the angle is off, the light will refract. Different parts of the wave hit the boundary at different times, causing the light to change direction.



Scatter

Electrons don't always re-emit light in a set direction; instead of transmitting or reflecting the waves, they send the energy out at a random angle, causing scattering. The amount of scattering depends on the type of atom and the frequency and wavelength of the light.



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A Model Aircraft THE RAF RED ARROWS HAWK

The British Aerospace Hawk is one of the most important British jets. Having first flown as the Hawker Siddeley Hawk in Surrey in 1974 the Hawk is still in production in the UK today and is sold to many different countries all over the world. The Hawk is considered a "low-cost" combat aircraft, in 2003 one would've reportedly cost you approximately £18 million!

Without doubt, the most famous of the 1000+ BAe Hawks produced are the aircraft which wear the distinctive colours of the Royal Air Force Aerobatic Team 'The Red Arrows', arguably the world's best and certainly the most famous aerobatic display team.

The Red Arrows have been performing their thrilling displays to audiences all over the world since 1965, fulfilling the role of Britain's most effective flying ambassadors wherever they appear. To join the Red Arrows display team candidates have to have completed a front line tour as a Royal Air Force pilot, have a minimum

of 1500 flying hours and be assessed as "above average" in their current RAF flying role. A maximum of three new pilots are chosen each year so the pilots of the Red Arrows really are the best of the best!

The Red Arrows have appeared in almost 5,000 displays in over 50 countries. A global television audience of over one billion people watched the flypast they performed at the London 2012 Olympic Games Opening Ceremony. The Hawks of the Red Arrows really are amongst the most famous aeroplanes in the history of aviation.

The Red Arrows Hawk is a British icon and you can recreate your own at home with an Airfix QuickBuild kit. QuickBuild kits give you the ability to recreate a wide variety of iconic aircraft, tanks and cars into brilliant scale models. No paint or glue is required, the push together brick system results in a realistic, scale model that is compatible with other plastic brick brands.

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Who do you think you are?

Discover what your genetic makeup can tell you about your ancestral journey

Nearly every cell in your body houses your all-important genetic information. Tightly coiled in the nucleus of each cell, deoxyribonucleic acid (DNA) forms the building blocks of what makes you, you. As the blueprint for our bodies, DNA can also reveal information about our ancestry.

In recent years, people have become increasingly interested in finding out more about their genetic origins. 23andMe, named after the 23 pairs of chromosomes in a normal human cell, are one of many companies heeding that call and digging into our DNA.

The way 23andMe identify your genetic ancestry is mostly a game of genetic *Guess Who?* By comparing each customer's DNA variants (differences in DNA sequence) with those of people from around the world, geneticists can match and eliminate geographical locations based on the

population's genes. Knowing which part of the world your ancestors came from, however, isn't the only historical information that can be extracted from your DNA. It can also provide some clues about your genes' journey to where you are now.

By analysing the mitochondrial DNA – which is inherited only from your mother – and the Y chromosome in males, geneticists can reveal the migrations of our ancestors. By looking at genetic variants and mutations, paternal and maternal lines are characterised into separate groups known as haplogroups. These tend to share similar geographical roots, and based on our current understanding of prehistoric human migrations, their footsteps can be followed across the globe from a single ancestor in Africa all the way to where you are now.

Within some people's DNA there are variants associated with our ancient human

relatives. Before the Neanderthals died out around 40,000 years ago they coexisted with *Homo sapiens* in parts of Eurasia, during which time the two species interbred. Remnants of these ancient relationships can be found in our genes; research suggests that the majority of Europeans and Asians have around two per cent Neanderthal DNA. This information is related to physical traits such as height and hair, and by testing our DNA scientists can estimate how many of these variants we have in common with our extinct Neanderthal cousins.

"Identifying our genetic ancestry is mostly a game of genetic Guess Who?"

It's as simple as AGCT

From mouth to monitor, how do DNA samples become a fact file?

1

Collection

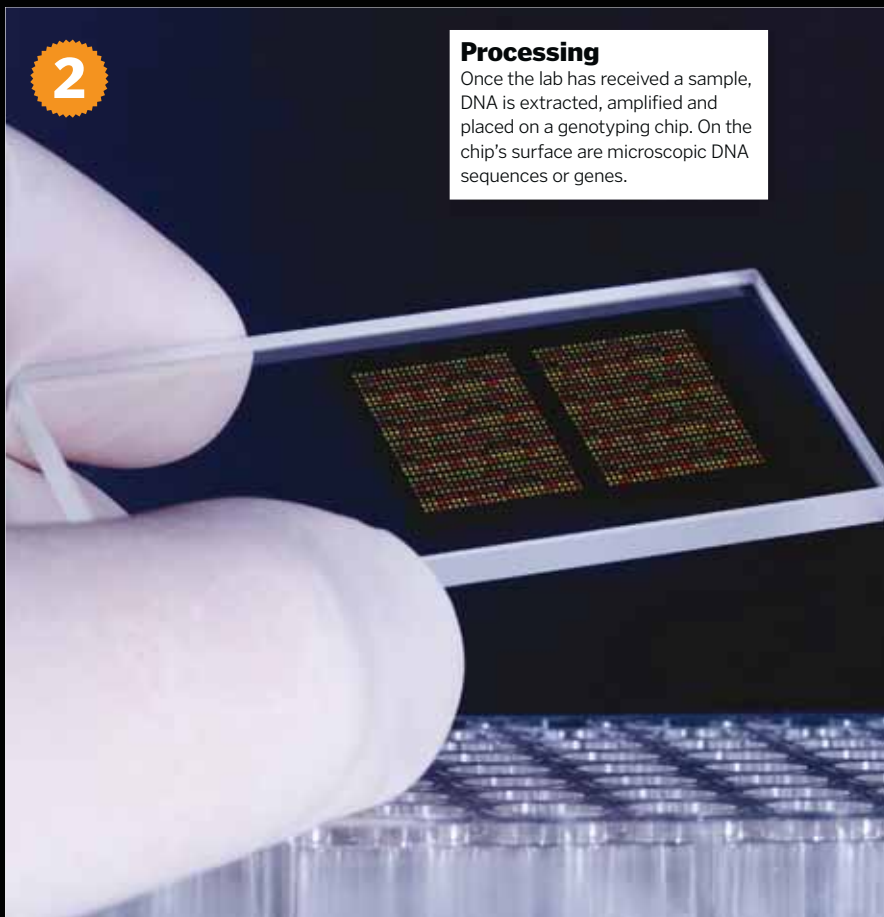
A saliva sample is collected in a tube and sealed to prevent contamination.

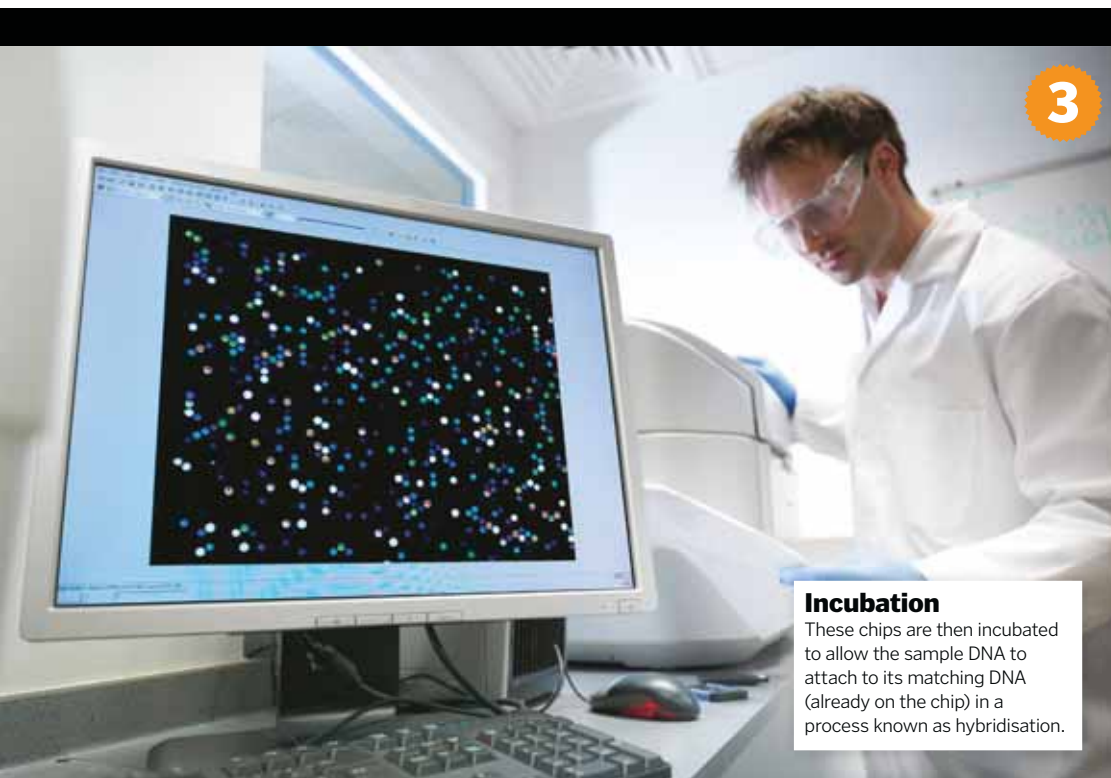


2

Processing

Once the lab has received a sample, DNA is extracted, amplified and placed on a genotyping chip. On the chip's surface are microscopic DNA sequences or genes.

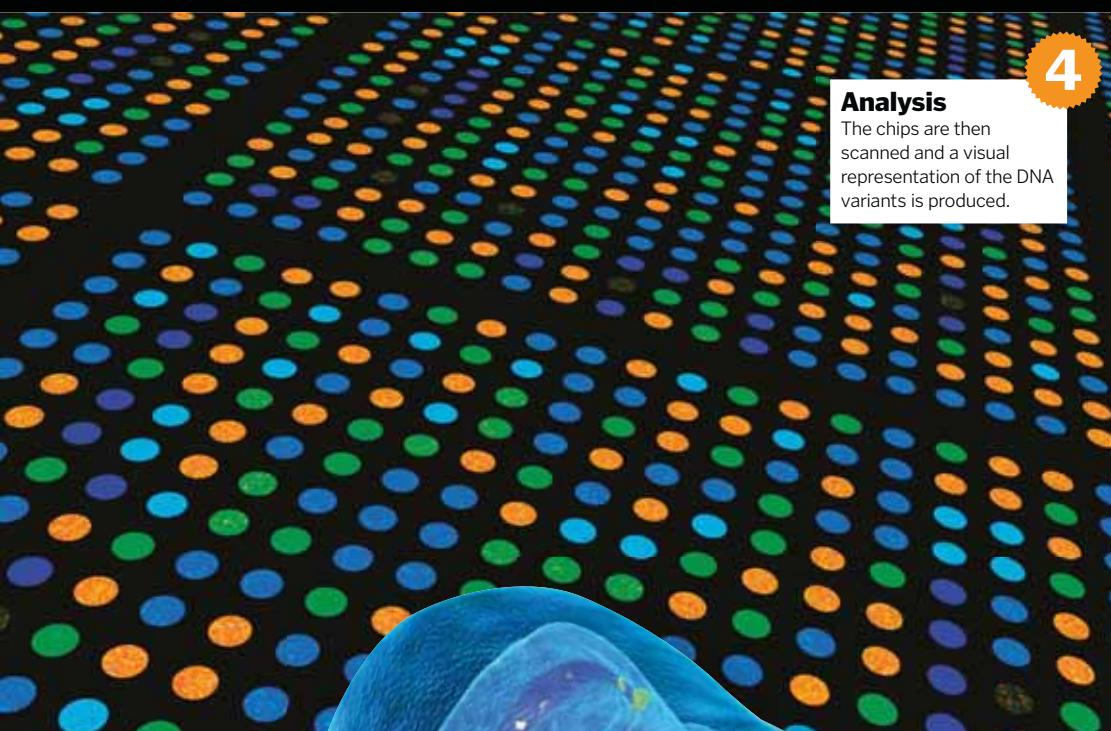




3

Incubation

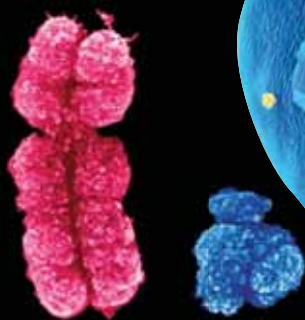
These chips are then incubated to allow the sample DNA to attach to its matching DNA (already on the chip) in a process known as hybridisation.



4

Analysis

The chips are then scanned and a visual representation of the DNA variants is produced.



Above: an X (pink) and Y (blue) chromosome. In order to establish paternal haplogroups geneticists take DNA variants from the male Y chromosome

5 Results

These variants are catalogued and compared to a resource database to give the results of the sample ancestry.



Scott's results

It came as no surprise that my results revealed that I'm

almost 100 per cent European, but even so it was interesting to discover my French and German roots. I was surprised by 23andme's ability to find out that I share a common ancestor with Irish royalty, Niall of the Nine Hostages, from the 4th century CE.

Ancestry composition

70.8% British & Irish
15.8% French & German
0.1% Scandinavian
13.0% Broadly northwestern European
0.3% Unassigned

Shares a common ancestor with

Niall of the Nine Hostages

Neanderthal variant (non-African average 280)

259



Charlie's results

My family history has always been a mystery because my

mother was adopted as a baby and there wasn't much information about her birth family. So we were really interested in learning about our immediate family and were really surprised to find out we're Irish – perhaps it explains my green eyes! Based on the information from 23andme we've been able to expand our own research to learn more about my mum's family.

Ancestry composition

84.5% British & Irish
5.3% French & German
0.4% Scandinavian
8.1% Broadly northwestern European
1.7% Broadly southern European

Shares a common ancestor with

Marie Antoinette

Neanderthal variant (non-African average 280)

264

Left: small amounts of DNA found in the mitochondria (inherited only from your mother) can reveal your maternal haplogroup



The evolution of sign language

Motion tracking reveals how new sign languages change over generations

Just as with spoken languages, people in different places use different kinds of sign language. Despite emerging separately, these languages share common features and seem to evolve in similar ways.

According to a study reported by the journal *Science*, emerging sign languages show similar patterns of development. Wendy Sandler studied Al-Sayyid Bedouin Sign Language, which appeared in the 1930s. Its inventors in

Israel used only their dominant hands to express themselves. As more people picked up the language they started to include their heads, faces and bodies to add more layers of meaning.

Using motion tracking to analyse the movements made by sign language speakers, Sandler then examined Israeli Sign Language. The pattern repeated again, with younger speakers using increasingly complex combinations of movements.

2 Head movement

Movements of the head and neck come second, helping to add context.

3 Expressions

Third are facial expressions, adding grammatical complexity in the form of clauses.

1 Dominant hand

When new languages first emerge, the dominant hand is used to make the signs.

4 Body movement

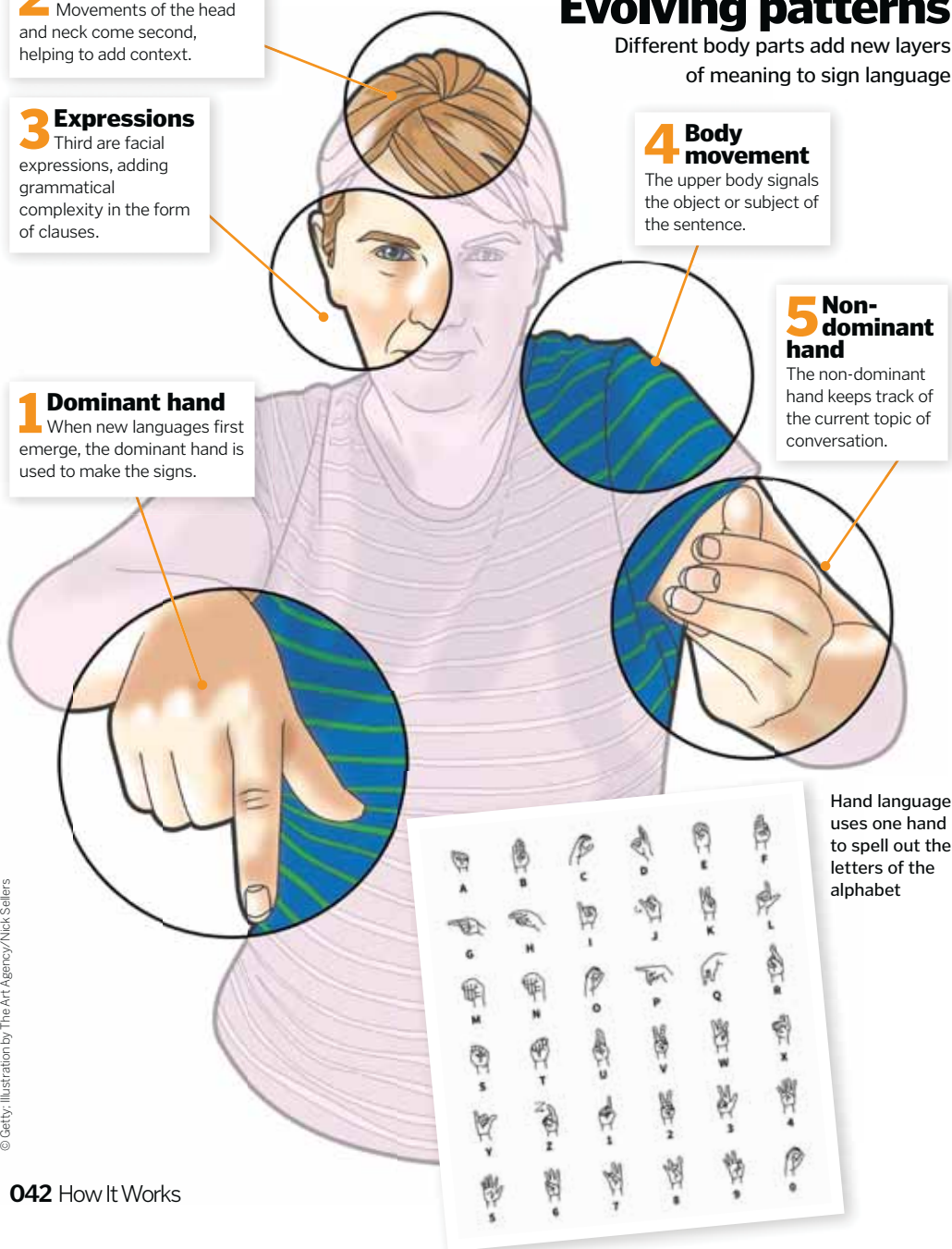
The upper body signals the object or subject of the sentence.

5 Non-dominant hand

The non-dominant hand keeps track of the current topic of conversation.

Evolving patterns

Different body parts add new layers of meaning to sign language



Hand language uses one hand to spell out the letters of the alphabet

Sweet science

Get your teeth into the chemistry used to make your favourite sweets

Table sugar, or sucrose, naturally forms crystals. These molecules line up in regular patterns held together by weak interactions. When sugar dissolves water interrupts these interactions, pulling the individual molecules into the solution. The higher the temperature, the more sugar can dissolve before the solution becomes saturated. As the mixture cools, the sugar starts to crystallise again.

To make hard sweets, confectioners take the mixture to a very high temperature, dissolving as much sugar as possible. They then cool it down slowly as sucrose molecules clump together to form crystal 'seeds'. As the temperature drops and more sugar comes out of the solution, these seeds become larger and larger, forming into the big crystals of crunchy rock candy.

Interfering with the crystal formation changes the texture. To make soft sweets like fudge, confectioners begin with less sugar. They stir the mixture, breaking up the crystal seeds to encourage the formation of lots of smaller crystals. They then make sure that it cools quickly, setting before the crystals get too large.

Cooling the sugar even faster stops crystal formation completely. The sugar sets in a disordered structure, enabling confectioners to make see-through glass sweets and candyfloss.



Candyfloss cools so fast that crystals don't have a chance to form

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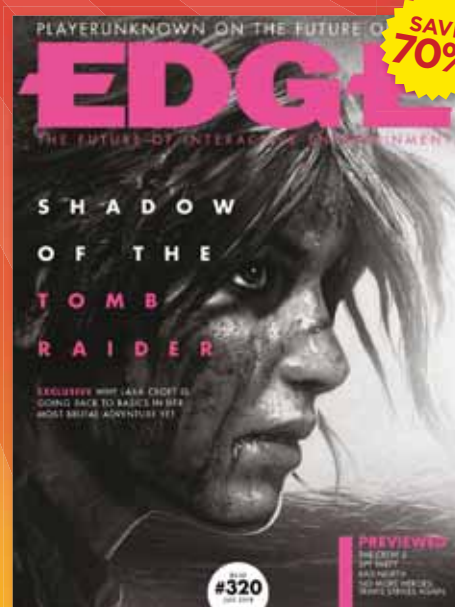
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SAVING

EARTH

How we can use observations from orbit
to protect our planet from disaster

FROM

Words by **Jonathan O'Callaghan**

SPACE



It might not look it, but our planet is a fragile place. A delicate balance of pressure, temperature and gases keeps us alive as our atmosphere lets in enough heat for us to thrive – but not too much that we get too toasty. For many years our planet has looked after itself with ease. Now, with humans on the scene, things are changing more than ever, from climate change to mass deforestation. If our planet is going to survive long into the future it's going to need our help.

Fortunately, we've got plenty of missions that are working for the benefit of our world already. Using observation satellites in orbit, scientists have been monitoring Earth for decades, watching how the planet pulsates and changes over time. From orbit we can watch how species migrate, identify and predict environmental changes and even fix problems.

A great example of this was the global effort to repair a hole in the ozone above the Antarctic back in 1987. Two years prior, scientists had discovered that chemicals known as chlorofluorocarbons (CFCs) – produced by fridges and aerosols, among other things – were causing the hole to grow. As a result countries around the world agreed to phase out the use of CFCs as part of the Montreal Protocol.

In early 2018, NASA announced that its Aura satellite had watched the hole successfully close, with it expected to fully repair as early as 2060 or as late as 2080. It was proof that we could work together to change the planet for the better.

Aura is part of a broader NASA project called the Earth Observing System (EOS). This programme, which began in 1997, has seen NASA launch missions and instruments into orbit. This has included the groundbreaking Landsat series of satellites, which have provided surface images of the whole globe. Then there's the Terra mission that launched in 1999 and studies clouds, sea ice and more from orbit. Most of these satellites are in polar orbits, which means they orbit the planet from top to bottom as Earth rotates underneath and gives them a global view.

Planning for the EOS began back in the 1980s, with NASA keen to regularly fly instruments for at least 15 years. "Human activity has altered the condition of the Earth by reconfiguring the landscape, by changing the composition of the global atmosphere, and by stressing the biosphere in countless ways," they noted in a handbook in 1993. "There are strong indications that natural change is being accelerated by human intervention."

More than two dozen missions have been launched as part of the EOS to date. Among the programme's many accomplishments, scientists watched as an ice shelf collapsed on the Antarctic Peninsula in 2002 using the Terra

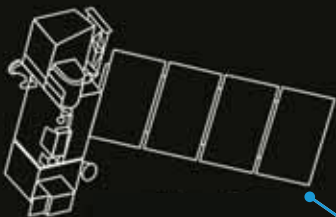
© Getty

**Sentinel-6**

The Sentinel-6 mission will measure the height of the oceans, as well as monitoring temperature changes in the atmosphere.

**Sentinel-1**

The two Sentinel-1 satellites provide continuous day and night imagery in all weather, which is useful for coordinating an emergency response.

**Sentinel-5**

The twin Sentinel-5 satellites, set to launch in the 2020s, will measure the composition of the atmosphere, including ozone and methane.

**Sentinel-5P**

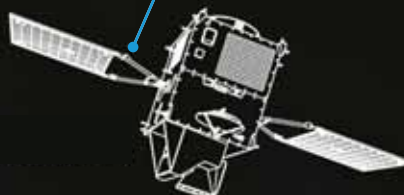
Launched in October 2017, this mission is a precursor to Sentinel-5 and will be testing out a spectrometer to monitor air pollution.

Sentinel satellites

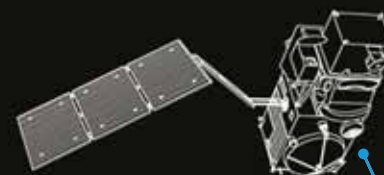
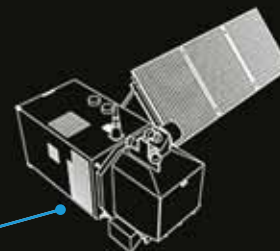
What can each of these ESA missions do in orbit?

Sentinel-4

When the Sentinel-4 satellites launch in the coming years they will be used to monitor the amount of trace gases and aerosols in the atmosphere.

**Sentinel-2**

The twin Sentinel-2 satellites can peer directly into the water columns of oceans and check on the health of coral reefs.

**Sentinel-3**

Sentinel-3A and 3B can monitor the amount of marine pollution and the productivity of life in the oceans with their imaging instruments.



An image of Mount Taranaki in New Zealand captured by the Landsat 8 satellite

satellite. The same satellite, along with the Aqua satellite launched in 2002, has provided a global view of how the vegetation cycle changes over the course of a year and the impact the climate has on it. Those same two satellites have also allowed us to see how summer sea ice in the Arctic is decreasing, which means that more of the Sun's light is being absorbed rather than reflected, raising global temperatures.

The EOS has helped in other ways too, such as enabling scientists to keep a close eye on the levels of toxic gases (like carbon monoxide emitted from massive fires) in the atmosphere. This allows people on the ground to be alerted to these dangers, and they can in turn be advised to limit their outdoor activity to protect their health. The EOS is even helping to track and monitor rare animals, such as chameleons in Madagascar. Here, scientists have been able to

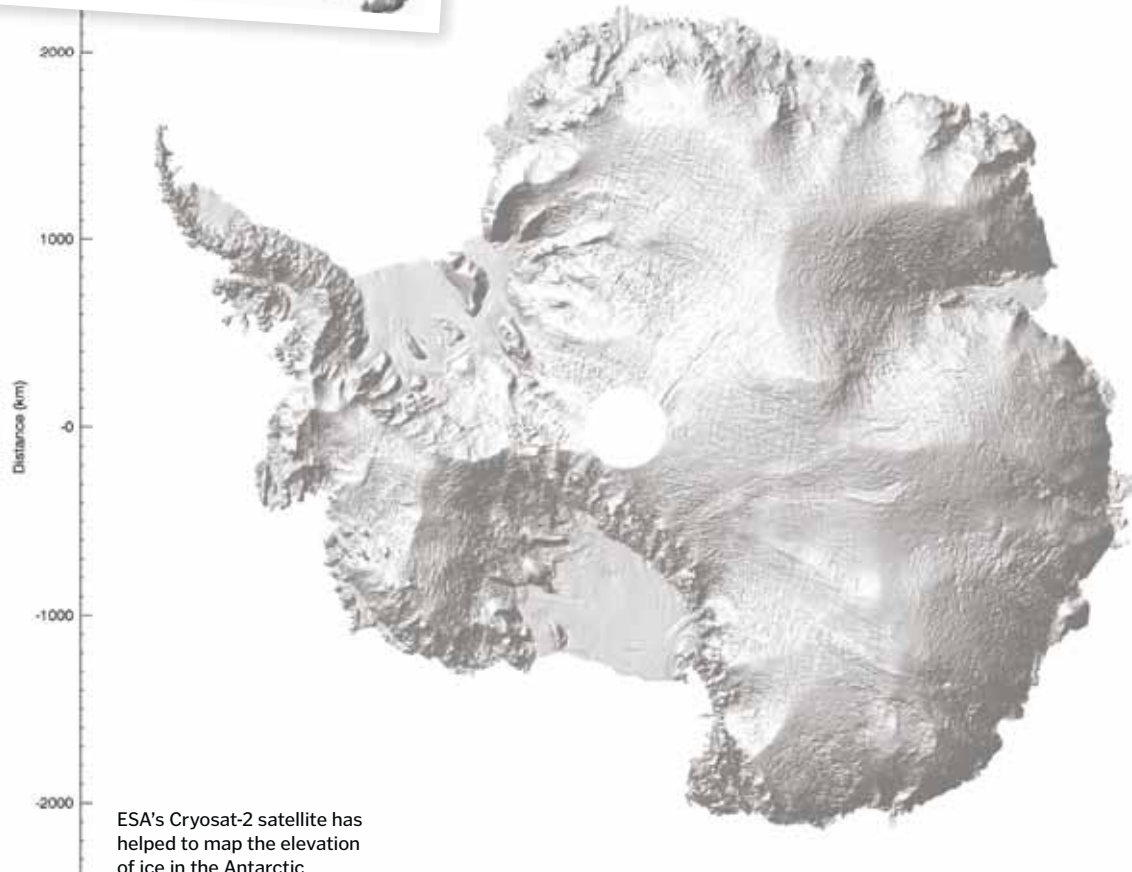
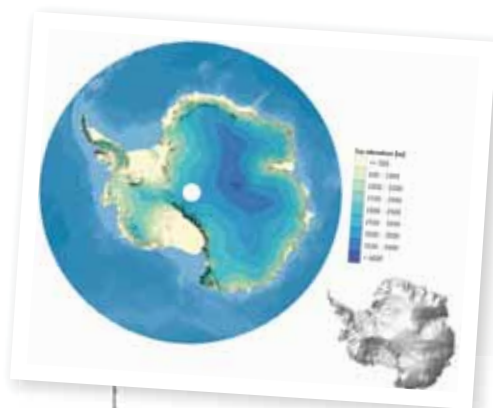
use satellite imagery, combined with known habitats of the animals, to map out where they are likely to be living. It would take survey teams on the ground thousands of years to replicate this information without satellites.

It's not just NASA that has been keeping a close eye on the planet. The European Space Agency (ESA) runs the Copernicus project, billed as the world's largest single Earth observation campaign. Previously known as the Global Monitoring for Environment and Security (GMES) programme, it began with the launch of the Sentinel-1A satellite on 3 April 2014. This

"Summer sea ice in the Arctic is decreasing"

radar imaging satellite provides images both day and night and during all weather conditions, and these are being used to map sea ice, track oil spills and much more.

This has been followed by half a dozen more missions, with the latest – Sentinel-3B – launching on 25 April 2018. This mission is focusing on monitoring the behaviour and health of the oceans, but it has a wide range of abilities. It flies in formation with its predecessor, Sentinel-3A, and together the two of them can provide global data for Earth across an entire day. The satellites can measure the temperature over oceans, as well as the colour and height of the sea. They can also monitor wildfires from space, check the health of vegetation and map land use around the world.



5 FUTURE EARTH PROTECTORS

- 1 2018 – Aeolus**
Due to lift off in August, ESA's Aeolus satellite will use laser technology to probe the atmosphere and study winds, helping to predict extreme events like hurricanes and El Niño.
- 2 2020 – Biomass**
ESA's Biomass mission will provide vital information about how forests are changing. It will use radar measurements to study the amount of biomass and carbon stored in forests.
- 3 2020 – Landsat 9**
Landsat 9 will be NASA's next great imager, designed to observe the global land surface and display both natural and human-caused changes on the planet.
- 4 2020s – Hyperspectral Infrared Imager (HyspIRI)**
This NASA mission will use infrared imaging to study how and when volcanic eruptions occur. It will also study soil health, monitor deforestation and provide an early warning of droughts.
- 5 2022 – FLEX**
The Fluorescence Explorer (FLEX), also from ESA, will aim to work out how carbon moves between plants and the atmosphere by measuring the light emitted by plants undergoing photosynthesis.



Monitoring disasters

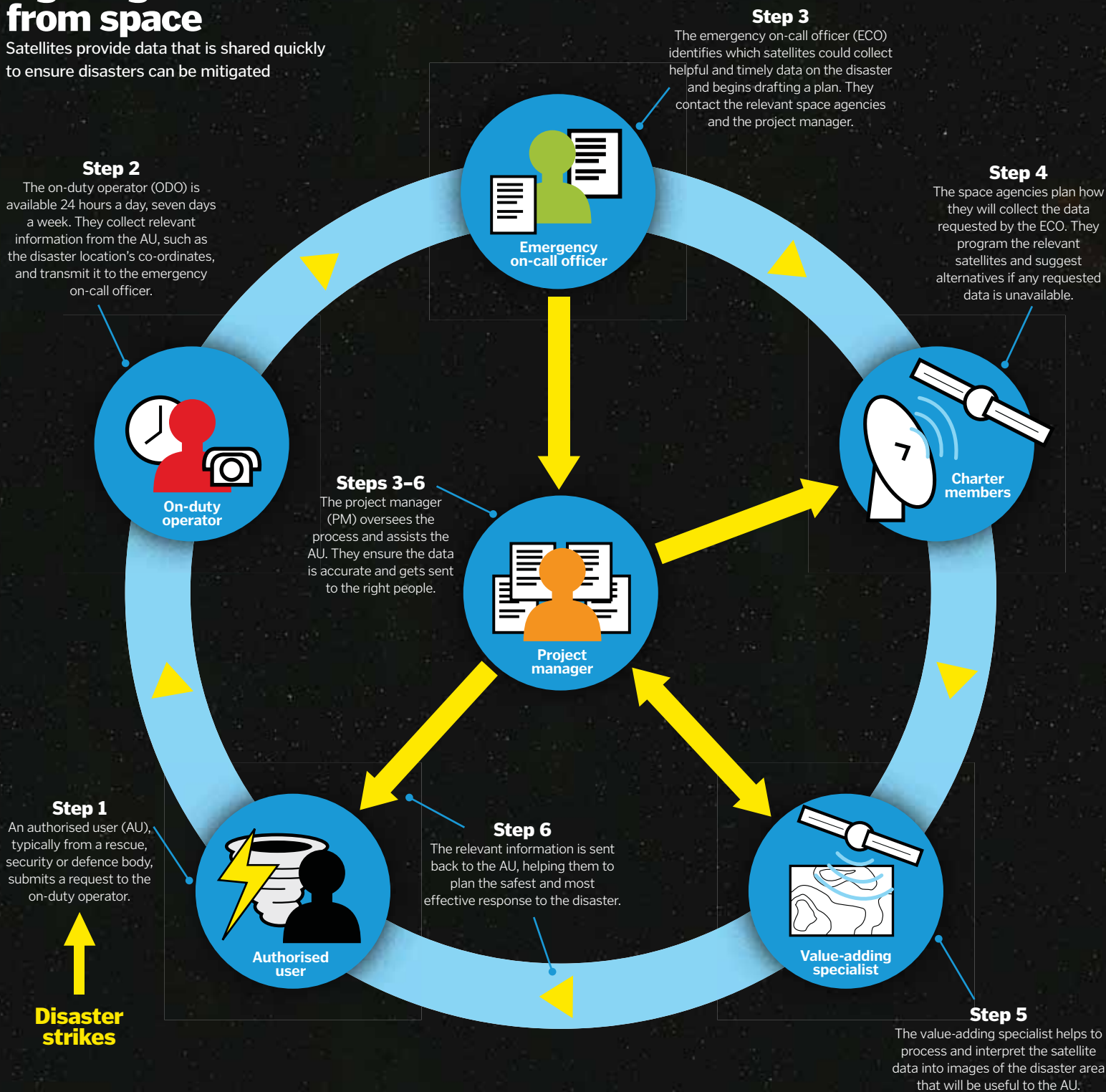
Earth is regularly rocked by natural disasters, but having a fleet of spacecraft in orbit is a pretty good way of keeping on top of them. In 1999, ESA and France's CNES space agency drew up the International Charter Space and Major Disasters, which includes 16 members

that share observations from their various satellites and available data on major events. This means that local authorities can more quickly respond to major disasters, such as sudden floods in Sri Lanka, using satellite imagery and data to support relief efforts.

Every six months a different member is responsible for being 'Charter Lead' and coordinating all efforts, providing a free service to any emergency services around the world that want to tap into the benefit of this potentially life-saving information.

Fighting disasters from space

Satellites provide data that is shared quickly to ensure disasters can be mitigated



ESA's Sentinel satellites have provided vital data on Earth's climate from space

NASA satellites found that 2017 had been the second warmest on record since 1880

There are more Sentinel satellites on the way too. In the coming years we'll see the Sentinel-4 and Sentinel-5 missions launch, studying the composition of our planet's atmosphere, while Sentinel-6 will measure global sea surface height for ocean and climate studies.

"Copernicus will help shape the future of our planet for the benefit of all," said ESA, also noting that it is the "most ambitious Earth observation programme to date," one that will provide accurate and timely data on the environment, climate change and more. All of this data is vital for directing climate policy and other human activities on Earth. By observing our planet around the clock from space we can see the direct effect that humans are having on it.

These are not the only climate-monitoring missions run by NASA and ESA. The former has a number of other missions, including the Deep Space Climate Observatory, which observes the

sunlit side of Earth. The latter has eight missions on the books in its Earth Explorer

programme, including a mission to study how Earth's gravity field varies over the surface of the planet, called the Gravity field and steady-state Ocean Circulation Explorer (GOCE), which ended in late 2013.

In 2016, countries of the world came together to sign the Paris Climate Agreement, a global effort to reduce carbon emissions to prevent the global average temperature rising by two degrees Celsius above pre-industrial levels. While the US later infamously pulled out of this agreement at President Donald Trump's request, it was proof that with enough level-headed minds – minds that can see the data from missions showing how the planet is changing – we can take meaningful action.

Human activity continues to have a major effect on Earth, for better and worse, and monitoring the changes we bring about is vital to our planet's survival.

ISS research

It's not just satellites that are saving us from space. Technology used on the International Space Station and experiments performed by astronauts can also improve life on Earth

Water purification

The technology that circulates and cleans the space station's water supply can help provide water filtration to villages where drinkable water is scarce.

Indoor air quality

When monitoring crop growth on the ISS researchers found a way to remove viruses and bacteria. The technique is now used on Earth to prolong the shelf-life of fruit and vegetables.

Coral reefs

Photographs taken by astronauts on the ISS have been used to check on the health of coral reefs, helping to preserve the ecosystems related to them.

Cancer detection

Techniques used for robotic arms on the exterior of the ISS have been employed in MRI scanners back on Earth to help look for breast cancer tumours.

Natural disasters

Like other satellites, the ISS can play a vital role in monitoring natural disasters from space. Different instruments are used to support decision-making on the ground.



TESS

How NASA's newest planet hunter will scour the universe for other worlds

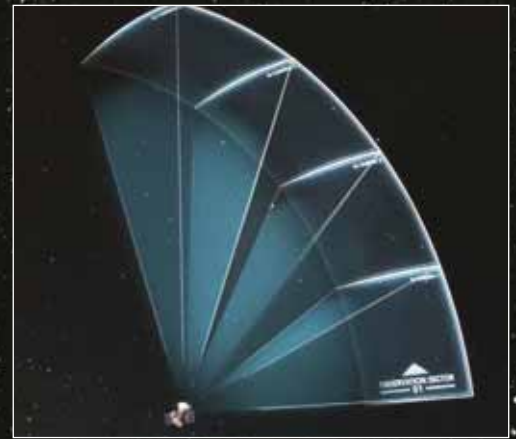
To date we have found several thousand worlds beyond our Solar System.

Known as exoplanets, some of them are relatively close to Earth, while others are thousands of lightyears away. We've managed to accumulate a pretty good collection, from Earth-sized worlds to gas giants like Jupiter, mostly thanks to NASA's Kepler telescope. But we're about to find a whole lot more.

On 18 April 2018, NASA's newest planet hunter, the Transiting Exoplanet Survey Satellite (TESS), was launched on top of a SpaceX Falcon 9 rocket. Placed in an unusual orbit around Earth, this satellite will continuously peer at the night sky in an effort to find worlds orbiting stars 30–300 lightyears from us. It's hoped it may find as many as 20,000 planets, more than five times as many as we've found so far.

TESS, which measures about four metres long, will search for planets using the transit method. This involves looking at stars and noticing the dip in light as a planet passes in front of them. This technique has already been employed with great success by Kepler, but TESS will take it to a whole new level by using four cameras – rather than Kepler's single camera – to look for planets. Its primary mission will last two years, during which time it will observe 85 per cent of the sky (an area 400 times larger than Kepler).

TESS will be focusing on bright stars, with most of the planets it finds being ranging between Neptune and Earth in size. A few hundred, however, are expected to be potentially rocky places less than twice the size of Earth, and some may even be habitable. Whatever TESS finds, the next few years promise plenty of exciting discoveries.



TESS will observe 85 per cent of the night sky, splitting it up into 26 segments over two years

This artist's concept depicts some of the exoplanet types TESS will be searching for



"TESS may find as many as 20,000 planets"

Inside TESS

How does this spacecraft work, and how will it look for planets?

1 Cameras

TESS has four wide-field cameras onboard, which will monitor bright stars for dips in light caused by orbiting planets.

2 Sunshade

This shields the cameras and spacecraft from the Sun's light to keep temperatures stable.

3 Reaction wheels

Four spinning gyroscope wheels will be used to point the spacecraft towards specific stars.

4 Antennas

The High Gain Antenna onboard TESS will send data back to Earth once every two weeks.

5 Thrusters

There are five thrusters onboard TESS to keep the spacecraft in its intended orbit.

6 Master computer

TESS has an onboard computer to control the spacecraft and its components.

7 Solar panels

The spacecraft runs on solar power, with the solar panels generating 390 Watts of electricity from incoming sunlight.

Right: TESS will find planets by looking for transits as they pass in front of their star

Stars

Each of the four cameras will be able to image thousands of stars every two minutes.

Field of view

The cameras will study an area of sky $24 \times 96^\circ$ for each segment.

Segments

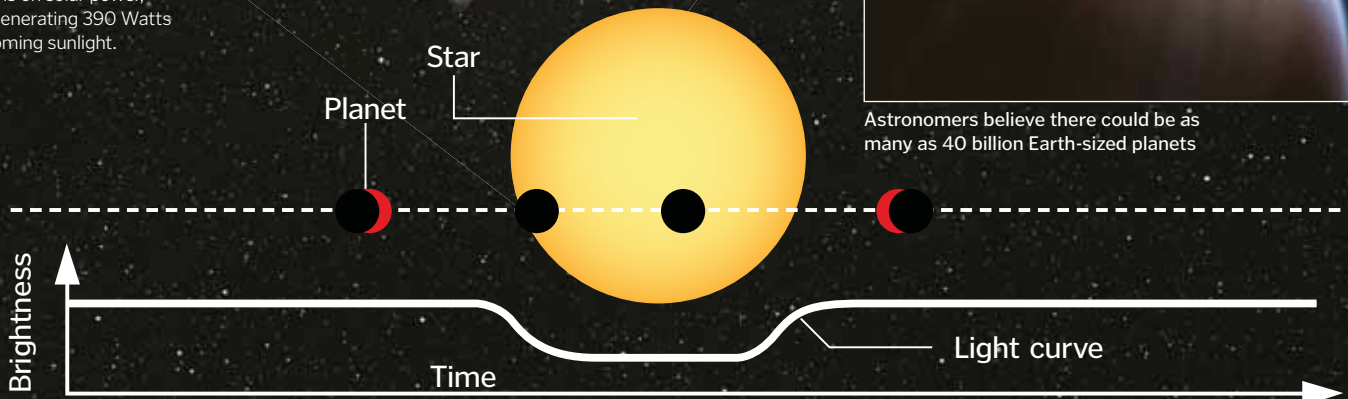
TESS will observe each of the 26 segments for 27 days before moving on to the next one.

Orbit

The satellite completes two orbits of Earth for every single Moon orbit at an angle of approximately 40° .



Astronomers believe there could be as many as 40 billion Earth-sized planets





EPIC ENGINE

Behold incredible creations from the world's master builders. With innovations across the ocean, on land and deep underground, the sky is no longer the limit

Words by **James Horton**

SOARING STRUCTURES

Amazing architecture and innovative designs that enable us to defy gravity

W350 wooden skyscraper

■ **Location:** Tokyo, Japan

■ **Progress:** Planning stages, completion target 2041

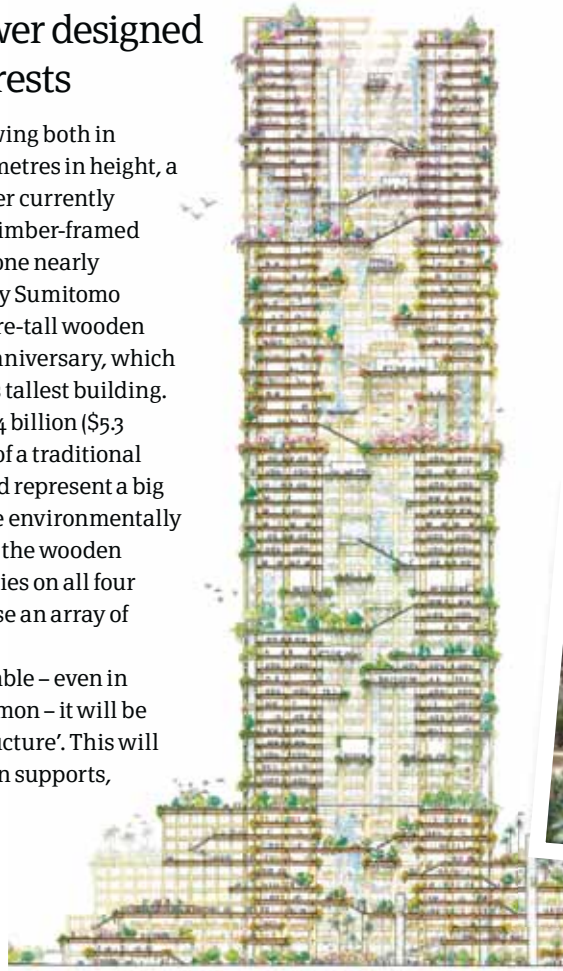
The timber-framed tower designed to change cities into forests

Tall wooden buildings are growing both in popularity and in scale. At 53 metres in height, a student residence in Vancouver currently holds the title of the world's highest timber-framed building, but Tokyo may soon boast one nearly seven-times taller. Japanese company Sumitomo Forestry Co have proposed a 350-metre-tall wooden skyscraper to celebrate their 350th anniversary, which if commissioned will become Japan's tallest building.

With a predicted cost of just over £4 billion (\$5.3 billion) – approximately double that of a traditional concrete skyscraper – the W350 would represent a big step towards Tokyo becoming a more environmentally friendly city. The organic aesthetic of the wooden structure will be bolstered by balconies on all four sides of the building, which will house an array of plant life.

To ensure the building remains stable – even in Tokyo, where seismic activity is common – it will be constructed using a 'braced tube structure'. This will involve a mixture of steel and wooden supports, with wood forming 90 per cent of the building's material.

The W350 will house shops, offices, residential units and a hotel



The W350 will promote urban biodiversity by embedding flora on all of its many balconies



Beijing Daxing International Airport

■ **Location:** Beijing, China

■ **Progress:** Under construction, completion target 2019

China's latest infrastructure project will cater for 100 million passengers every year

Despite its size, the People's Republic of China has a relatively low aviation capacity. The Beijing Daxing International Airport was proposed to improve this, and it's set to do so in a big way.

This gargantuan airport, designed in collaboration with Zaha Hadid Architects, will feature four runways at the time of its opening and an intricate, flower-inspired terminal space built using 1.6 million cubic metres of concrete and 52,000 tons of steel. In total, the new airport will encompass an area of 47 square kilometres, and it has rightly been described as a testament to China's world-leading production capabilities.

Initially, Beijing's new airport is predicted to transport 45 million passengers per year, but this figure is expected to grow to a whopping 100 million passengers, making it one of the busiest airports in the world.



By 2025 it is hoped that the airport will be able to accommodate 630,000 flights a year



When it opens in late 2019, the Beijing Daxing will be the world's largest international airport



GOING UNDERGROUND

With advanced tunnelling technologies, these projects are changing the infrastructure beneath our feet

Crossrail

■ **Location:** London, UK

■ **Progress:** Under construction, opens fully December 2019

The tunnels that represent the pinnacle of precision engineering

The Crossrail network was an ambitious undertaking, requiring eight tunnel boring machines to work 24 hours a day, seven days a week for three years. During that time the machines carved tunnels totalling 42 kilometres in length, but distance wasn't the only obstacle the Crossrail engineering team faced. To save on time and expenditure, the new tunnels ran as close as possible to their optimal path underneath London and came precariously close to existing infrastructure.

The machines had to avoid building foundations, sewers, utility tunnels and existing underground rail lines. Under the densely occupied underground of Tottenham Court Road, for example, the new tunnel came within one metre of an operational tube platform. Over 200,000 concrete segments were used to assemble the tunnel walls, and this structure was supplemented in places by additional sprayed concrete, which was used to reinforce the cross-passages that served to connect parallel rail lines.

Laser guidance

The machines are governed by a laser guidance system, which ensures the tunnel ends up within 1mm of its target destination.



Stabilising pressure

To prevent the tunnel face collapsing, dirt removed by the cutting wheel is collected behind its face to provide stability.

Cutting wheel

The front face of the machine slowly revolves and carves away dirt using disc cutters and scraping tools.

Providing thrust

Once the concrete segments have formed a stable wall, pistons are pushed against them to drive the cutting wheel forwards.



The Boring Company

■ **Location:** Los Angeles, US

■ **Progress:** Trials ongoing

The tunnel company with an incredibly ambitious goal – to beat a snail in a race

Tunnel boring machines are slow – so slow, in fact, that a soft-soil variant is 14-times slower than a snail. But the Boring Company's founder, Elon Musk, has laid down the gauntlet: he wants his machine to beat a snail in a race.

Designing a carving machine that digs over 14-times faster than a traditional one is no mean feat, but Musk has a few ideas as to how this can be done. Most importantly, by placing vehicles inside the tunnel on an automated electric skate network, the tunnel's dimensions can be reduced substantially. This paves the way for an automated shuttle system that's set to revolutionise city travel, and it could be coming soon.

Inside the Boring Loop network



1 Departure

Private vehicles – along with public transport vehicles carrying between eight to 16 passengers – would enter the tunnel network at designated entry points.

Material analysis

Dirt being carried away on the conveyor belt is analysed to ensure the correct type of cutting wheel is being used.



Tunnel boring machines

The giant mechanical worms that create perfect tunnels and never need to rest



Crossrail's TBMs carved out approximately 3.4 million tons of earth over three years

Dirt removal

Clay, chalk, soil and other geological materials are carried away from the cutting face via a revolving screw mechanism.

2

Lock and key

Reinforced concrete segments are lifted into place via a mechanical arm. A conical-shaped keystone is added last to lock the segments in place.

3



Emisor Oriente water tunnel

Location: Mexico City, Mexico

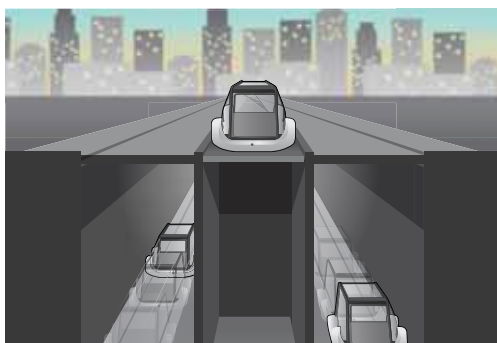
Progress: Under construction, completion target 2018

The buried structure built to preserve Mexico City

Sewers aren't typically seen as the most glamorous of constructions, but the Emisor Oriente wastewater tunnel will soon be performing an invaluable service for Mexico City.

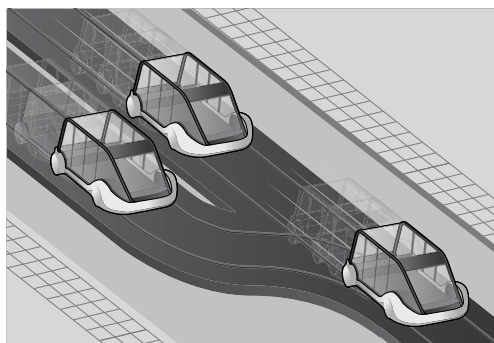
The city's growing population has led to an increased demand for water, which is pumped from the lakebed that lies beneath it. However, this has resulted in the city filling the void where the water used to be. Mexico's capital is sinking – possibly by as much as 12 metres in the past 100 years – and is now vulnerable to flooding.

Fortunately, engineering innovation is on hand to help. The Emisor Oriente will shift rainfall and wastewater at a rate of 150 cubic metres per second through its 62-kilometre length. Carved using six custom-built boring machines equipped to deal with the complex ground conditions in Mexico, the tunnel will be robust for years to come thanks to its wall of reinforced steel and concrete segmental rings.



2 Descending

The entry points would operate as automated vertical lifts, which would safely descend from the surface into the tunnels below. From here the vehicles would merge into the relevant lane.



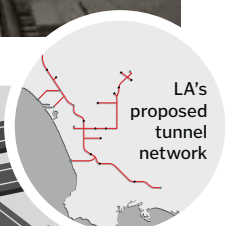
3 Gliding

Rather than driving independently within the tunnels, vehicles will be carried on a Loop system, an electric skate network that will ferry vehicles to their destinations at 200–240kph.



4 Future plans

There are plans for a 4.3km tunnel to be excavated in LA as a proof-of-process, but The Boring Company have also proposed a network of possible expansion routes across the city.





OVER WATER

How engineers harness the power of rivers and span huge natural barriers

Three Gorges Dam

■ **Location:** Sandouping, China

■ **Progress:** Completed, fully operational as of 2012

Meet the hydroelectric juggernaut that divides China's Yangtze River

The Three Gorges Dam is a monster. Its 2.3-kilometre length, 115-metre base width and maximum height of 185 metres spans the Yangtze River, making it the largest hydroelectric power station in the world.

By incorporating 27.2 million cubic metres of concrete and more than 460,000 metric tons of steel into its design, the dam supports an enormous reservoir that is capable of holding up to 42 billion tons of water.

Suffice to say, this dam can put out a lot of power. Estimated to generate 22,500 megawatts at maximum capacity, or around 11 times the energy output of the Hoover Dam in the US, the Three Gorges Dam has been pivotal to China shifting away from its reliance on fossil fuels and towards sources of renewable energy.

As well as generating energy, the dam was designed to alleviate flooding of the Yangtze Basin

The bridge is built to withstand earthquakes, super typhoons and being struck by a cargo vessel

Hong Kong-Zhuhai-Macau Bridge

■ **Location:** Lingdingyang Channel, China

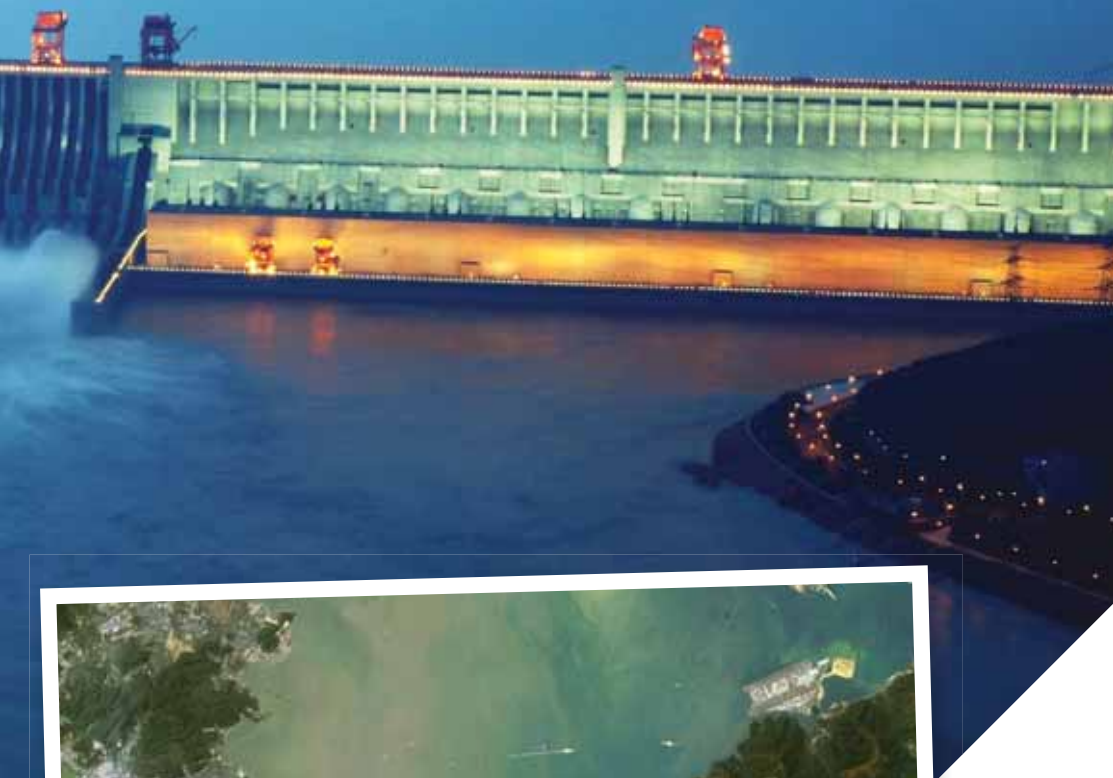
■ **Progress:** Complete, opening 2018

The human-made thread of immense scale being built to connect three of China's most integral cities

The cities of Hong Kong and Zhuhai and the region of Macau have long been hindered in their interactions thanks to the Pearl River Estuary that separates them. But the three look set to become tied together in 2018 thanks to a land bridge that



The Three Gorges Dam cost \$37 billion (approximately £28 billion) to build



The bridge's construction could even be seen in satellite imagery, pictured here by Landsat 8 in 2015

will span around 55 kilometres – 20-times longer than the famous Golden Gate Bridge.

A considerable portion of the bridge – almost 30 kilometres of it – will straddle the estuary, and vehicles will travel over the water in three lanes on both sides. Artificial islands will then connect the bridge section to a 6.9-kilometre underwater tunnel, which will be submerged to allow ships to traverse the water. Official projections believe the bridge will reduce travel times between the cities from four hours to just 30 minutes, and what a sight people will behold as they travel.

"The bridge will lower travel times from four hours to just 30 minutes"

ENGINEERING BLUNDERS

Kemper Arena, Missouri, US

In 1979, the Kemper Arena boasted a roof designed to hold water and release it slowly. The building wasn't equipped to deal with a rainstorm, however, and the weight of the pooled water soon proved too great and the roof collapsed.



Walkie Talkie skyscraper, UK

London's well-known 'Walkie Talkie' building is eye-catching due to its concave shape. Unfortunately, this design choice concentrates sunlight onto the ground below, generating enough heat to melt the bumper of a Jaguar.



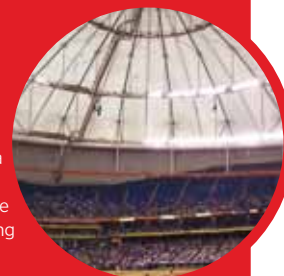
Tacoma Narrows Bridge, Washington, US

To save on cost, the engineers of the Tacoma Narrows Bridge used cheaper and insufficient materials during construction. This made the structure very unstable in high winds, and it soon collapsed after a particularly gusty day in 1940.



Tropicana Field stadium, Florida, US

Tropicana Field is home to the Tampa Bay Rays baseball team. Somewhat bizarrely, the stadium has a fixed roof, meaning that baseballs sometimes collide with the lighting, obstructing potential home runs and showering players or fans with shards of glass.



John Hancock Tower, Boston, US

John Hancock's namesake acquired a poor reputation shortly after construction was completed when its windows began falling out onto the streets below. It wasn't long before huge swaths of the window panes were empty and had to be filled with plywood.





HEROES OF... TECHNOLOGY

Lamarr had an 'inventing room' in her home and shelves full of engineering books

Lamarr used her profile to help the war effort through fundraising



A life's work

Lamarr's beauty and brains combined to change the world

1937

Kiesler signs a contract with MGM Studios, moves to Hollywood and changes her name to Hedy Lamarr.

1957

Lamarr's technology is adapted for use in transmitting the positions of enemy submarines.

1914

Hedwig Kiesler is born in Vienna, Austria-Hungary, on 9 November.

1942

Lamarr and composer George Antheil are granted a patent for their Secret Communications System.

Hedy Lamarr

The leading lady who paved the way for Wi-Fi technology

On the big screen, Hollywood siren Hedy Lamarr captivated audiences with her stunning beauty and acting talent, but when the cameras weren't rolling she could be found developing a technology that would go on to change the world.

Born in 1914 in Vienna, Austria-Hungary, young Hedwig Kiesler (her original name) dropped out of school to pursue acting, first in Czechoslovakia and then Hollywood, where she changed her name to Hedy Lamarr. Despite not completing her education, she retained a passion for knowledge and loved to tinker with contraptions in her trailer. She came up with an idea for an improved traffic stoplight; a tablet that would dissolve in water to create a carbonated drink; and, while dating aviation tycoon Howard Hughes, she helped him develop a racing airplane to sell to the US Air Force.

However, by far her most successful creation was 'frequency hopping'. When World War II broke out, the Jewish-born Lamarr felt uncomfortable living in luxury in Hollywood while her people suffered horrific persecution in Europe, so she decided to use her brain to help the war effort.

She had picked up a great deal of knowledge about weapons technology while married to her first husband, munitions manufacturer Fritz Mandl, and along with her friend and composer George Antheil she came up with a revolutionary idea that would prevent the Allies' torpedoes from being intercepted by the enemy.

Although they were granted a patent for their 'Secret Communications System' in 1942, the US Navy turned them away. Lamarr then offered her weapons expertise to the National Inventors' Council but was told that she should use her looks to help the war effort instead.



Lamarr became a spokeswoman for war bonds during WWII

Lamarr's brains were overshadowed by her beauty throughout her life. While she achieved worldwide fame as 'the most beautiful woman in the world' and as the star of such films as *Algiers*, *I Take This Woman*, *Come Live with Me* and *Samson and Delilah*, her contribution to science and technology went largely ignored.

In the 1950s the idea of frequency hopping was finally adopted by the military, but because her patent had expired Lamarr went uncompensated. Later, it became critical for the development of wireless communication, making the Bluetooth and Wi-Fi technology that many of us use every day possible, but still she received no credit.

It wasn't until the final few years of her life that she was honoured with an award for her groundbreaking invention. Later, after her death at the age of 85, she was inducted into the National Inventors Hall of Fame.

Today, Hedy Lamarr is rightly remembered not only as a glamorous star of the silver screen, but also for her brilliant and revolutionary idea which now connects all of the small screens in our pockets.

THE BIG IDEA

Frequency hopping

During World War II, the Allies' radio-controlled underwater missiles could be easily detected by German submarines because the signals were broadcast over a single frequency. To solve this problem Lamarr and piano composer George Antheil developed a system called 'frequency hopping', which could rapidly switch the signal to one of 88 different frequencies – the same number of keys on a piano – seemingly at random. Only those who knew the chosen combination of frequencies could intercept the signal, while everyone else just heard noise. This later formed the basis of the spread spectrum technology used to prevent interference in Bluetooth, Wi-Fi and GPS communication.



The Secret Communications System was intended to protect the Allies' torpedoes

5 THINGS TO KNOW ABOUT... HEDY LAMARR

1 She was a plastic surgery pioneer

In later life Lamarr gave her surgeons new ideas for cutting and folding her skin to better hide the scars. Her techniques became widely used in the industry.

2 She raised millions for the troops

After being turned away by the National Inventors' Council, Lamarr helped the war effort by becoming a spokeswoman for war bonds and managed to raise \$7 million in one night.

3 She was typecast

Lamarr's beauty eventually proved to be a curse, the actress growing bored of being cast in movies just for her good looks, saying, "Any girl can be glamorous, all she has to do is stand still and look stupid."

4 She has an 'Oscar for inventing'

In 1997, Lamarr became the first woman in history to receive the coveted Invention Convention's BULBIE Gnass Spirit of Achievement Award, known as the 'Oscars of inventing'.

5 She became a recluse

Towards the end of her life, Lamarr became intensely private, rarely venturing out of her home. Instead she spent up to seven hours a day talking to people on the phone.

1997

The Electronic Frontier Foundation gives Lamarr and Antheil the Pioneer Award for their work.

2014

Lamarr and Antheil are posthumously inducted into the National Inventors Hall of Fame.

1962

The US Navy begins to use Lamarr's invention on ships involved in the Cuban Missile Crisis.

2000

Lamarr dies on 19 January of heart disease in Florida, US, aged 85.

"Lamarr's brains were overshadowed by her beauty throughout her life"

Inside the HTC Vive Pro

We find out how the latest virtual reality headset works

The original HTC Vive is widely considered the best of the major VR headsets since it launched, and now HTC is back with an updated version. The Vive Pro is a new, more powerful version of its famous headset. It's got a new design. It's got higher screen resolution. And it's got plenty of great new features that make the VR experience even better than before.

The update starts with the design, which is focused on player comfort. The first Vive was comfortable but could feel heavy on the front of your face during longer playing sessions. The new Vive spreads the weight out across your head and adds built-in surround sound headphones. This means you can play for longer and get the best possible sound experience without having to wear a separate heavy pair of your own headphones.

The tech inside the headset is better too. The two screens inside the goggles are higher resolution, which means there are more pixels in front of your eyes. This makes games look smoother, and everything looks that little bit more realistic.

Then there are the two cameras pointing out of the front of the headset. These are spaced out at around the same distance as your eyes, and they can capture a view of what's in front of you. This means the headset can detect where you are in a room to avoid you accidentally crashing into walls! But how does all this tech fit into a compact pair of goggles? Let's find out...

Head strap

The head strap features a curved design and more padding for better comfort. The hinged design makes it easier to put on too.

Under the hood

What tech powers this all-new VR headset?



The front of the Vive Pro features 32 sensors to capture the incoming IR beams projected by the base stations

HTC have worked hard to keep the weight of the headset low and evenly distributed

Headphones

The stereo headphones are built into the head strap to provide surround sound audio without the need for extra headphones.

Front plate

This is the front plate that holds most of the tech. It's full of slots and grooves where boards, sensors and cameras clip in.

IR sensors

These 32 sensors can see the IR beams that are fired out by the Vive's two base stations, so the headset knows exactly where it is in 3D space.

"Games look smoother, and everything looks that little bit more realistic"



Lenses

These two lenses are what you look through to see the VR world. The concave lenses make a flat screen appear 3D to your eyes.

Chip board

This is where the majority of the important chips inside the headset are located. These powerful components are all attached to a small circuit board.

Main board

This is where the IR sensors feed data to, allowing the Vive to show the right images to you as you play.

Dual cameras

These two cameras face out the front of the headset. As well as capturing the room around you, they help the Vive track your hand movements.

Display

This is one of the two displays. Each one is 1440x1600, creating a full image of 2880x1600 - that's a whopping 615 pixels per inch!

Below: HTC's original Vive headset (left) was released in 2016 and has sold over 1.3 million units

How the Pro improves on the Vive

As well as featuring more pixels, the Pro offers an AMOLED screen (compared to the Vive's OLED). This means blacks are deeper and colours are more vibrant. It also supports more than two base stations, so you can play in a larger area - up to 100 square metres. Dual microphones make your voice clearer when you're talking to friends online, and those built-in headphones make audio better too. However, all of this comes with some caveats, the first being that you'll need a slightly more powerful computer to get the HTC Vive Pro up and running - and they can be very expensive. Then there is the £799/\$799 price tag, which is £300/\$300 more than the standard HTC Vive. Both systems will play the same games, but they'll look crisper on the Pro.





Inside a Taser

How these weapons use electricity to bring suspects down

Typically tucked away in a police officer's holster, Taser guns have the power to bring criminals crashing to their knees. Once triggered, these weapons deliver 1,200 volts of electricity to the body of a target typically for five seconds.

The suspect is first met by the laser guide, which can reach a distance of about 7.6 metres. Once positioned, the officer can pull the trigger and deliver a shocking shot. Bursting from the

gun's cartridge, two needle-style probes propel through the air to pierce the target's skin. Electricity then flows from the gun through insulated wires to ultimately hijack the nervous system of the unfortunate victim.

Also known as 'electro-muscular disruption' guns, this method of defence results in the suspect's muscles contracting, temporarily paralysing them as they fall to the ground.

The X26 model was first introduced within the UK's police force in 2003



Cartridge doors

These protect the gun's contents while it's not in use. Once triggered, the doors are blown off due to the increased internal pressure.

Compressed nitrogen

In the same way a bullet is fired using gunpowder, cylinders of compressed nitrogen gas launch the Taser's probes when the trigger is pressed down.

Probes

Once attached to the suspect, these probes deliver a high-voltage electrical charge to immobilise them.

Identification tags

Whenever a Taser is fired, small confetti-like ID tags are released, each with the gun's serial number.

Generator

This is the source of the electrical current that will flow through the insulated wires to the probes.

Inside the Taser

How do Tasers deliver a shot strong enough to stop a suspect?

Samsung S-Ray

This new wearable speaker promises to send sound straight to your ears – without headphones

Could this be the beginning of the end for headphones? At the International Consumer Electronics Show (CES) earlier this year in Las Vegas, Samsung showcased a prototype of one of their innovations said to send sound straight to the ears from a collar style contraption called the Neck Bend.

The idea of a wearable speaker isn't something completely new to the market; companies such as Bose have launched a similar-looking neckband speaker, the SoundWear. However, what makes this device different is its ability to isolate its sound to the wearer without disturbing those around them.

Invented in Samsung's Creative Lab, the S-Ray (Sound Ray) is said to use ultrasonic modulation to direct sound to the wearer's ear. This works by the speakers emitting sound as a very narrow, focused beam of ultrasound, which we cannot hear. When the beam encounters an object – in this case, your ears – the ultrasonic signal transforms into 'normal' sound waves that you can hear.

Another benefit of the S-Ray's unique design is that the wearer can listen to their music without being isolated from the world around them. While it's still very much a prototype, should the S-Ray take off the future of the audio industry could head in a whole new direction.



The S-Ray Neck Bend is one of three speakers, including a mini portable speaker and a smartphone attachment

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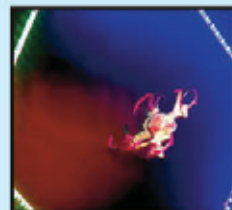
Learn coding &
electronics in
Inventor School



Build your own 3D printer
from scratch in
3D Printing



Build & programme
advanced robots in
Robowars



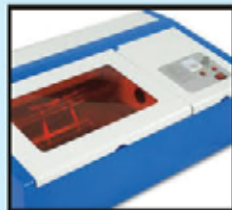
Race drones & build
programmable race lights in
Drone Racing



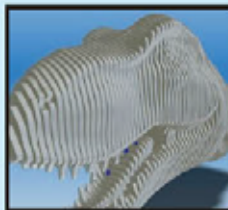
Build your own electronic
gaming system in
Laser Tag



Combine 2D, 3D,
electronics & coding in
Maker Week



Learn 2D design &
making in
Laser Maker



Learn 3D CAD &
3D printing in
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Design your own games,
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Come as a day camper at one of our three venues in the South of England, or join hundreds of other young people from around the UK and overseas at our flagship residential camps where you also spend evenings playing laser tag, learning extreme soldering and disassembling electronics.

Want to Know More?

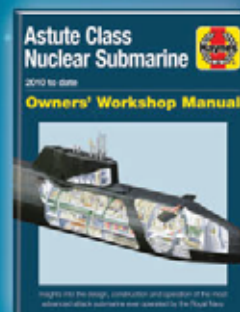
Tech Camp is the UK's original camp of its kind and remains the only one specialising in teaching coding through advanced take-home projects. It's perfect for creative youngsters who like making things (or taking them apart!) or show those who are forever playing games how to start designing their own.

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KEEP OUT

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ALIEN INVASION

Venture behind enemy lines on the biodiversity battlefield and weed out the ecological imposters

Words by Ella Carter



KEEP OUT

KEEP OUT

KEEP OUT

KEEP OUT

Aliens are living among us. Humankind cannot escape and we are entirely at their mercy... It may sound like science fiction, but these alien invaders are nothing of the sort. However, they don't hail from the outer reaches of our universe. In fact, they're more likely to be found lurking under a rock in your back yard. In biology, an 'alien' or invasive species is quite simply one that is thriving somewhere it doesn't naturally belong.

How these uninvited guests arrive and take hold can happen naturally, or it can be at the hands of us pesky humans. Sometimes the species are transported to their new habitats by mistake, where they hitch a ride on wind or water and get deposited in a new ecosystem. Other times they are introduced by human intervention, perhaps as a solution to another problem without proper knowledge of the species, or as a cute – yet underestimated – novelty that grows into a widespread pest.

As our ancestors began to travel further and further afield, they took plants and animals of all forms along with them for the ride – often unknowingly. In the ocean, larvae of all kinds can be whisked across the planet within ballast water on ships; creatures are transported within goods along trade routes; stowaways in baggage or on clothing can go anywhere in the world just by hopping on a plane with us – the list is endless! But once a species has found an environment in which to thrive, these introductions can have disastrous consequences for populations of native plants and animals.

In the UK, American mink were introduced in 1929 to bolster the fur trade. However, thanks to escapees and deliberate releases, the population

has exploded throughout the last century as they have very few natural predators. Unfortunately, the mink's preferred prey is the water vole, and the native population has crashed as a result. Sadly, this is the pattern for the vast majority of alien invasions, where they push out the native species and make a bid to take over.

Just like the American mink, the best alien invaders are the ones who are hardy, sturdy and opportunistic. Being able to withstand harsh and often changeable conditions and survive on a wide variety of prey is essential for an invasive species; sensitive, delicate and slow-growing life forms need not apply.

Another reason why these species are able to take hold so well is because the new ecosystem will not often have any natural predators for the species. When nothing eats it, there's nothing to keep its population in check.

Florida's Everglades house an excellent example of this in the form of the mighty Burmese python. Native to Southeast Asia and growing up to seven metres long, these are popular exotic pets, but they can soon become unmanageable. The swamps of the Everglades are now rife with Burmese pythons that became too much of a demand for their owners and were released into the wild. Feasting on wading birds, the colossal snakes have very few natural hunters, allowing their numbers to flourish, to the detriment of local wildlife.

Another extreme case of species invasion is that of the water hyacinth in Lake Victoria. First introduced as a pretty flowering plant, the 1990s saw the South American weed spread rapidly throughout parts of Africa's largest body of water

Terrorising natives in the Everglades, Burmese pythons have few natural predators



"Sensitive, delicate and slow-growing life forms need not apply"

until it completely covered huge swathes of the lake in thick mats of green floating leaves. Fully covering the surface meant that oxygen and light could not reach the organisms in the water, forcing fish and other aquatic critters to leave or perish and killing off plant life rooted below. The hyacinth was outcompeting every other life form for essential resources.

The plants and animals were not the only life forms to have been choked by the hyacinth invasion. The problem became so bad that entire fishing villages had to be abandoned, as the dhows could not get through to land catches. On top of this, rail-ferry links were delayed – sometimes for weeks on end – because ships were not able to dock at wharves.

This illustrates how invasive species can have a surprisingly significant impact upon human life. From zebra mussels clogging up boat propellers across entire oceans to Japanese knotweed wrecking the foundations of houses, these species can wreak havoc.

For farmers who grow essential crops that provide us with food and sustenance, invading species cause a myriad of issues. Non-native plants can often grow faster and larger than the crops they compete with, and thanks to this they can attract more pollinators, which causes yet more of a struggle.

Insect invaders will feast on crops, and then there is the added issue of the extra pesticides that are used to eradicate them. Not only does this impact the environment by introducing



Who knows what problems these spiny, poisonous Indo-Pacific lionfish could cause in the Atlantic? Only time will tell



often harmful chemicals to natural habitats, it also results in a heavy financial burden for the agricultural sector.

Disease is also a major problem. Invaders can bring pathogens with them that can spread to native species and cause a huge decline in population numbers. In the 1970s, American crayfish were brought to the UK for export to the Scandinavian market. However, with them came the 'crayfish plague', a disease that almost wiped out the UK's local white-clawed crayfish species. American crayfish also burrow into banks and cause erosion, sediment pollution and even collapse. All of this costs us extra time, money and resources to rectify.

In the case of the water hyacinth in Lake Victoria, yet more invasive species were introduced in an attempt to bring shoreline communities back from the brink. Two types of South American water weevil with a voracious appetite for water hyacinth were released into the lake. Within a few years the weevils were able to chomp their way through a significant part of the weed mat, meaning fishing could restart. Even so, the hyacinth still prevails today.

While it may seem that an invasive species can only ever be bad news, there are some slightly more positive examples where they can actually benefit local wildlife. Take the European rabbit, which was introduced to Britain in the 12th century and is now a key part of the countryside food chain, providing an essential food source for native predators such as birds of prey, foxes

and Scottish wildcats. Another example is human-made forests of evergreens like Douglas firs (originally from North America and brought to the UK for timber), which are havens for our native endangered red squirrels.

So how do we keep track of and manage the spread of these species in a modern world where anyone can go anywhere? The key lies in monitoring, biological control, eradication and prevention. On a global level, huge databases like the Global Register of Introduced and Invasive Species help to catalogue and monitor the impact these species are having on our environments and their pervasive existence in specific countries.

On a much smaller level, local monitoring is essential for understanding the impact of a species on an ecosystem. For example, the European gypsy moth caterpillar has been wreaking havoc on forests in North America, stripping trees of their bark and leaving them vulnerable to pests and disease. Local monitoring means that ecologists can track the spread of the species and devise on-the-ground strategies to contain a potential outbreak of marauding insects.

"There are some examples where alien species can benefit local wildlife"

The UK's most prolific invader is the harlequin ladybird. It outcompetes our natives for food and shelter



ALIENS BY NUMBERS

20-30%

of invasive species worldwide cause problems for native habitats

Between 1970 and 2007, the number of alien species in Europe increased by

76%

Combined, the area of the US effected by invasive plant infestations is roughly the size of California



Annually, invasive species cost

\$120 BILLION

in the US and

£1.7 BILLION

in the UK

It is estimated that invasive species have contributed to the decline of

42%

of threatened and endangered species in the US

Around 10 new

species are introduced in Europe each year

The introduction of the salmon parasite *Gyrodactylus salaris* could cost the Scottish economy an estimated

£633 million

Japanese knotweed can grow at a rate of

1 metre per month

Non-native rodents have invaded over 80% of the world's islands



OUT

KEEP OUT



Never release pets

If you keep exotic pets, no matter where you live in the world, don't ever be tempted to release them into the wild. This is how boa constrictor populations have boomed in Florida.



Clean your kit

When you're off adventuring, whether that's on land or sea, be sure to clean your kit when you're done. This means brushing down and washing everything from boats to boots to ensure stowaways aren't taken with you when you leave.



Be proactive

Get to know local species and learn to recognise the ones that don't belong and how to deal with them. For example, if you think you have Japanese knotweed in your garden you'll need to deal with it quickly.



Pay attention to customs

Island nations are especially vulnerable to the disruption that non-native species can unleash on their natural environments, so pay attention to customs notices when they ask you not to bring plants or animals with you into the country.



Buy native plants

When you're sprucing up your garden, do your research and buy native seeds and plants to boost their populations. Try not to buy strong species from other countries, as these may out-compete with the homegrown plants for resources.



Monitoring can also gauge the effects of relatively new invaders, such as the lionfish that are now present in Atlantic waters on the southeastern coasts of the US, Caribbean and the Gulf of Mexico. Thought to be another case of exotic pet release, the impact that these Indo-Pacific natives are having on their new marine habitats is yet to be fully understood.

After the monitoring comes the solution, which is in the form of control or eradication. Biological control is the most sustainable way of managing invasive species breakouts. This involves using another species to control the spread of the invader – the Lake Victoria weevil is a great example of this.

In extreme cases, eradication becomes necessary to protect the delicate ecosystems under threat. This type of management was put to excellent use with the case of the Galápagos goats. These unassuming ungulates were roaming across the islands of Pinta, Santiago and northern Isabela, grazing on the delicate flora and outcompeting the ancient and unique native Galápagos species for food and habitat. It may sound barbaric, but to remove the goats was the only way to ensure that the island's locals could thrive once more.

Finally, there is prevention, which is undoubtedly the best way to protect native environments from alien invaders. Island nations are the most at risk, so this is why places like Australia and New Zealand have such strict customs regulations surrounding what can and cannot be brought into the country.

So the next time you see a weed flourishing in a garden, a predator taking the lion's share of prey, or a huge colony of animals thriving together, ask yourself, do they belong here? The answer – and the consequences – may just surprise you.



So-called for its tendency to catch a ride and move onto pastures new, the gypsy moth caterpillar is threatening American forests

GLOBAL INVASIONS

Hardy and competitive species are spreading across the world – here are a few of the most prolific alien invaders!



Grey squirrel

Hailing from the US, the eastern grey squirrel arrived in the UK during the 1870s. It brought the parapoxvirus with it, which has been deadly to our native red squirrels.



Zebra mussel

From the Caspian and Black seas of Russia and Ukraine, ballast water of ships brought these prolific mussels to the US. They are now widespread across North America and some of the worst aquatic biofoulers.

Kudzu vine

Native to eastern Asia, this prolific vine is capable of choking its surroundings in a matter of days. It was brought to the US as a solution to combat soil erosion.



KEEP OUT KEEP OUT KEEP OUT

Raccoon

First introduced as exotic pets, the hardy raccoon (originating from the US) is taking Europe by storm. Able to survive on a highly varied diet, these furry fiends can spread infectious disease.



"When nothing eats it, there's nothing to keep it in check"

Japanese knotweed

This infamous building-rupturing weed was introduced to the UK by the Victorians as an ornamental plant and cattle feed. Unfortunately, it grows so fast and nothing eats it or competes with it, making it very hard to control.



Cane toad

Around 3,000 of these toads were released in Australia in 1935 in a bid to control the cane beetle population. They now number in the millions and are one of Australia's biggest pests.



Possum

Introduced from Australia in 1837 for the fur trade, possums are now New Zealand's biggest pests. They destroy natural forests and infect cattle with bovine tuberculosis.

Famine weed

This destructive herb is poisonous to livestock and humans and first became a major issue after Cyclone Demoina in 1984. It has since spread rapidly, causing huge issues across the African continent.



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We've got a leak

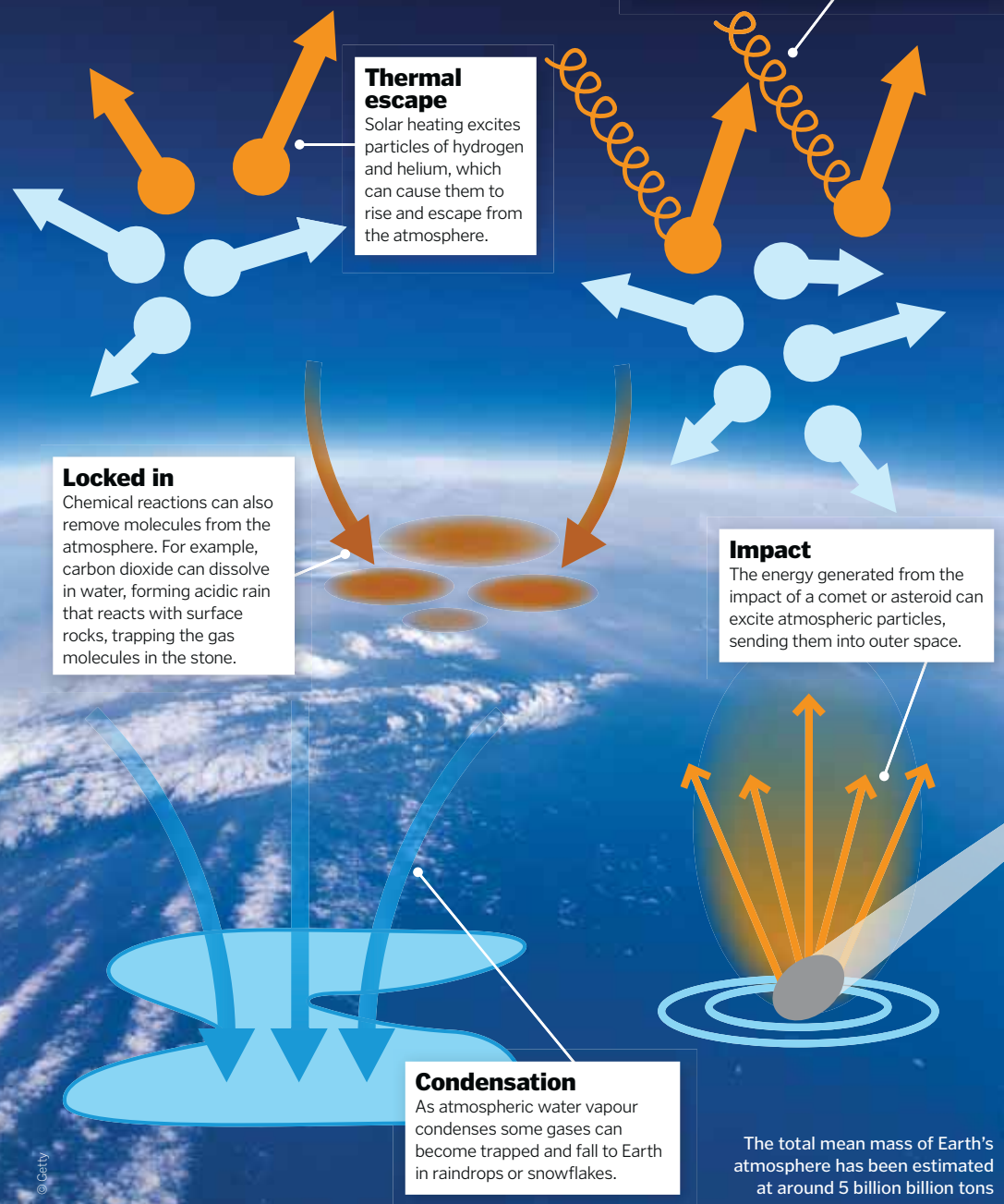
Our atmosphere is escaping into outer space, but how long until we run out?

Our atmosphere is vital for life on our planet to survive. However, some processes can knock atmospheric gases out from our protective bubble and into space. It is estimated that around 180 kilograms of hydrogen and three kilograms of helium are lost from Earth's atmosphere every minute.

Solar radiation is the main contributing factor to the loss of our planet's thin blue line. This process is not unique to Earth; you only have to look at Mars' barren surface to see the effects of dramatic atmospheric loss. Thankfully, it's going to take another 3 billion years before we become the next Red Planet, so there is no immediate panic.

Escape artists

How does some of our atmosphere end up taking a one-way trip into space?



Tree tumbos

The prehistoric plant that makes living in the desert look incredibly easy

In the vast expanses of the arid Namib Desert of southern Africa there are few leafy plants that can survive. The tree tumbo, however, has been perfectly adapted to the desert for millennia.

These dwarf trees may grow up to two metres in height (although usually less than one metre) and have a wilted, messy appearance. With rainfall being scarce in the desert, the tree tumbo has developed the ability to gather moisture from the air by drinking in the water from fog and dew.

Water droplets form on the surface of their ribbon-like leaves, then the beads roll down to the ground and soak into the parched floor, travelling down to the roots below. This isn't their only sustenance, however; tree tumbos have also tapped into the groundwater with their long and aptly named taproots.

These clever plants were first discovered in 1859 by Austrian botanist Friedrich Welwitsch, hence their scientific name *Welwitschia mirabilis*. Since its discovery researchers have found examples of these self-sufficient plants that may be over 1,000 years old.

The tree tumbo's bizarre appearance has led to it being referred to as one of the world's ugliest plants



The total mean mass of Earth's atmosphere has been estimated at around 5 billion billion tons

**Rock fall**

This is the fastest type of landslide and involves rocks rapidly and suddenly falling from a cliff or steep slope. The loss of ground support can be caused by ice wedging, root growth or ground shaking.

Debris slide

These are often caused by heavy rain or rapid snowmelt, causing soil and fragmented rock to move down a steep slope. These tend to occur in areas undercut by erosion.

Types of landslide

Landslides can be classified into five main categories, each behaving differently depending on the terrain and conditions

What causes a landslide?

The forces of nature involved in these sudden and treacherous collapses

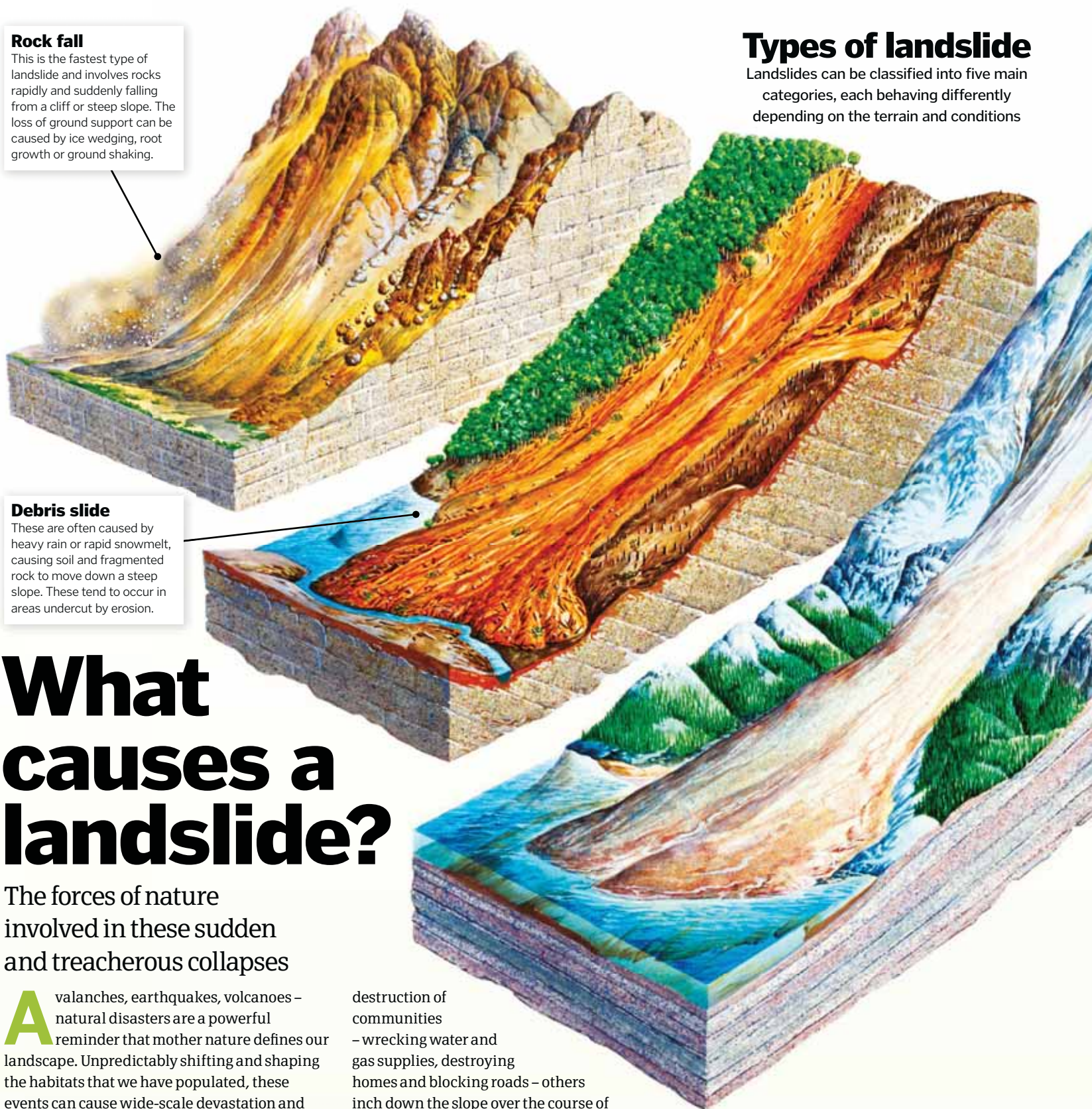
Avalanches, earthquakes, volcanoes – natural disasters are a powerful reminder that mother nature defines our landscape. Unpredictably shifting and shaping the habitats that we have populated, these events can cause wide-scale devastation and dramatic changes on the Earth's surface. Landslides are one of these natural disasters.

The term 'landslide' describes a category of mass movement that happens on cliffs and mountain faces. They occur when the rock, earth and debris clinging to the side of a mountain or slope succumb to the forces of gravity. While some types of landslide hurtle towards the ground and result in catastrophic

destruction of communities – wrecking water and gas supplies, destroying homes and blocking roads – others inch down the slope over the course of years. Seismic activity and weather conditions like extreme rainfall have been shifting soil for millennia, but increased human activity means they are occurring even more frequently.

One of the most commonly observed causes of landslides occurs when cliffs or mountains become heavily saturated. The soil can slip more easily in areas of deforestation, for example, because there is no root system to protect

against erosion. Clear-cutting methods of timber harvesting, which pull up existing root structures, increase the likelihood of a landslide occurring. Mining with detonation techniques, which generates strong vibrations that shudder through the ground, can also enhance the risk of a landslide.



Mudflow

This is the sudden and very rapid movement of saturated soil (soil filled with water) down a slope. These are often triggered by earthquakes or volcanic activity.



Any sort of destabilisation of earth can lead to catastrophic landslides

Slumping

A slumping landslide results in a large block of material moving down a curved surface and results in scarps (small crescent-shaped cliffs). These are often caused by seismic activity, freezing and thawing or water saturation.

Downhill creep

This is a slow, downward progression of earth caused by numerous tiny movements that create permanent deformations of the land. They can lead to broken walls, leaning poles and curved tree trunks.

"Landslides occur when the rock, earth and debris clinging to the side of a mountain succumb to the forces of gravity"



Sunseeker's headquarters and main assembly facility are located in Poole, on the UK's south coast



HOW TO BUILD SUPERYACHTS

We go behind the scenes at Sunseeker's factory in Poole to learn how some of the world's most impressive luxury yachts are built



Over 2,500 staff at Sunseeker work together to produce the company's iconic luxury yachts

BUILD A YACHT

Words by **Charlie Evans**

Superyachts are the essence of luxury. They offer uninterrupted panoramic views of the ocean, state-of-the-art technology and a seemingly effortless capacity to cruise through the water. But behind the gleaming hull and polished wooden floors, a complex array of plywood and fibreglass houses thousands of metres of electric cables, powerful engines and computer systems. All of this is the result of an incredible engineering and design process – a product of hundreds of thousands of construction hours.

Sunseeker International is world renowned for dominating the luxury yacht industry. Famed for their bespoke products, they carry designs through from the first conversations with the clients, transforming ideas and sketches into computer-generated schematics before constructing and handcrafting the entire vessel within a couple of months.

Sunseeker's giant factory in Poole in the UK is spread across several shipyards, with the process working on an assembly line. The factory is impressive, but there is a noticeable lack of large machinery across the manufacturing line for the company's 116 and 131 Yachts. Instead, the factory is bustling with people who work on

© Sunseeker



painting, fitting components and laying out wires. Our guide is Matt Francis, one of the on-site general managers, who explains the lack of machinery.

"You can get machines for these things. You can get spray guns for fibreglass, instead of rolling these sheets. But you'd have to change the settings for every boat, so it works better by hand. That's why almost everything you can see is hand built."

Across the shipyard almost every part of the yacht is being created by Sunseeker; we watch as the skilled teams work in synchronicity to build each part of the yacht's interior, from the beds and cabinets to the wiring weaved beneath the floors and between the walls. While other manufacturers tend to purchase pre-made furniture and components, Sunseeker prides itself on producing most of these parts at their own factory.

At the start of the process the hull is little more than a layer of painted gel inside a mould. This mould is shaped to include space for the parts to be added later down the manufacturing line, including the windows, portholes, lights and engines. The layer of gel will eventually form the gleaming high-quality coating on the outside of the yacht, but for now it is lined with fibreglass and carbon fibre. Knitted sheets are added layer upon layer then saturated with resin, which hardens to form the strong hull. Once set, the hull is lifted by a crane and carried to the next section of the factory.

The next stage of the manufacturing line looks very different from the first. The boat's hull is freed from its mould and layers of fibreglass and carbon fibre are applied to strengthen it. "The boat really starts to get its layout now, it looks like the floor plan of a house," says Matt as he

points to the exposed rooms being built into the hull. "You can see the bulkheads are there now, and where the cabins will be, and the en-suites, the galley, the stairs. We'll start to build the boat up now."

The carpenters are creating the components on site using durable hardwood. These are then fixed in place with high-strength adhesive before the engines are installed and the decks are fitted. Carpenters, laminators, electrical engineers, plumbers all work together across the boat at this point.

Next, the yacht's interior framework is added in. The stairs have gone from basic plywood shapes to polished steps. The engines and gearboxes have been installed on vibration mounts to limit the sound permeating the boat when they are powered up. You can trace the fuel lines all the way from the front to the back of the boat. Standing above the ship looking at the parts about to be pieced together, it's fascinating

to see how the vessel is gradually taking shape.

The decks and hull are fixed together in the next stage using high-adhesive glue. "The deck follows the same process as the hull mould," explains Matt. "When finished, the deck lifters spin it around upside down and it comes out of the mould tool."

Below: Individual rooms are laid out by carpenters, electricians, mechanics, plumbers and engineers all working together across the yacht

Completed surfaces are wrapped in protective blue plastic to shield them during the final stages of construction. The superyacht is manoeuvred using giant hydraulic cradles from the main shipyard into a hangar for the remainder of the work. The teams then get started on completing the interior with a meticulous attention to detail. The wiring, plumbing and furnishings are all installed to the client's original specifications.

The final stage of superyacht construction takes place on the water just outside the shipyard. A sea trial is required to make sure everything is working as it should, and a team checks every single surface for imperfections. After a thorough clean and the final installation of a few lights, the yacht is complete. The Sunseeker superyacht is ready to start cruising, carrying its new owner out into the open seas within the most luxurious of surroundings.



Above: While the hull is being finished the upper decks are being built almost simultaneously



A team coats the inside of the hull's mould with fibreglass during the first stages of construction



Q&A

Jean-Baptiste Soupez



We speak to the senior lecturer of Southampton Solent University's world-leading yacht design and composite engineering courses

What does the first part of the design process look like when you've decided to build a new yacht?

The starting point of the project defines the vessel. The client's input is paramount at this stage, and key decisions are made on [matters from] the size of the vessel to the area of operation. Some very specific design requirements are included, such as the number of Jacuzzis and the colour of the carpet.

What is the next big step in the process?

Conceptual design. This is an aesthetical design involving several hand sketches, then refined 3D models. Virtual reality has become more popular, allowing the designers to walk the client through their proposed design. The naval architect assesses the potential future design issues, such as challenges in meeting the rules and regulations, concerns about the amount of power or the stability. This is followed by the bulk of the work for the exterior and interior designers. Technical elements are covered, including hydrostatics and stability, structure, power required and engineering systems onboard. The final phase is generally the shipyard's responsibility. They produce the very fine details, such as the route for electrical cables and piping.

What design features are most important?

An increasingly important aspect is to keep the centre of gravity of the vessel as low as possible to guarantee stability. On sailing yachts we use deep keels, but on power superyachts there is no keel, so this is more challenging. It is common to use lighter materials higher up to lower the centre of gravity but also decrease the overall weight. Design features such as a bulbous bow are also used to reduce resistance. Without the bulbous bow a large wave would be created at the front of the vessel, leading to a higher drag. But by using a bulbous bow a wave forward of the bow is created, which then interacts with the vessel's wave to cancel it by destructive interference.

How is the yacht's power determined?

To work out the amount of power needed to propel the vessel at a given speed the resistance must first be assessed. This is done with a towing tank [shown on the lower right]. A model of the vessel is towed at different speeds and the resistance is measured. A mathematical model is then applied to scale it to full size and accurately predict how much power the vessel will require. A suitable engine can then be chosen.



A yacht's shape and design are an important factor in its performance



Sunseeker pride themselves on handcrafting each yacht's fixtures and furnishings

Hydraulic swim platform

This is a submersible swim platform that replaces a typical ladder. It lowers to water level to allow guests to easily board the yacht after a swim.

What makes a superyacht?

How these vessels combine luxury with the latest tech

Communication technology

GPS, radio and radar make navigating the open ocean easier and enable communication with onshore authorities and other ships.

Extras

The only limit to superyacht luxury is the imagination (and budget) of the client. Other common features include swimming pools, hot tubs and watercraft docks.

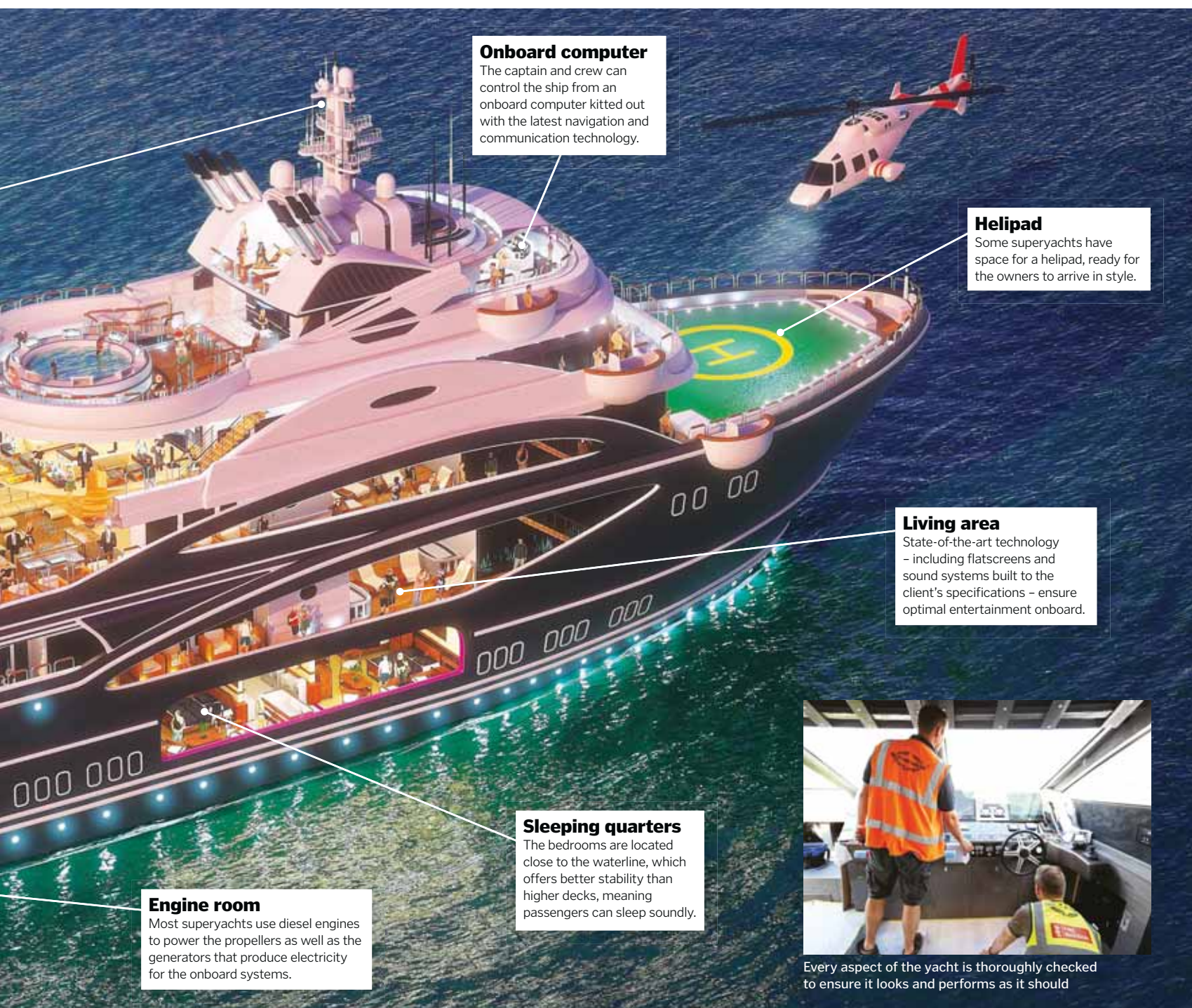
"Virtual reality has become more popular, allowing designers to walk the client through their proposed design"

Propellers

Propellers are powered by the engines, providing the thrust required to drive and turn the yacht.



Once the yacht is finished it undergoes sea testing and final inspections before setting sail with its new owner



Onboard computer

The captain and crew can control the ship from an onboard computer kitted out with the latest navigation and communication technology.

Helipad

Some superyachts have space for a helipad, ready for the owners to arrive in style.

Living area

State-of-the-art technology – including flatscreens and sound systems built to the client's specifications – ensure optimal entertainment onboard.

Sleeping quarters

The bedrooms are located close to the waterline, which offers better stability than higher decks, meaning passengers can sleep soundly.

Engine room

Most superyachts use diesel engines to power the propellers as well as the generators that produce electricity for the onboard systems.



Every aspect of the yacht is thoroughly checked to ensure it looks and performs as it should

All aboard the mega yachts



Al Mirqab

This \$250-million (£189.7-million) yacht was built for Qatar's former prime minister and foreign minister, Hamad bin Jassim bin Jaber Al Thani. It comes complete with onboard cinema, sun deck and swimming pool.



Dilbar

This giant superyacht is owned by Russian oligarch Alisher Usmanov, who uses the \$256-million (£193.8-million) vessel – complete with its own distinctive helipad – to visit his private islands.



Eclipse

Russian billionaire Roman Abramovich owns this \$1.5-billion (£1.1-billion) yacht, complete with a submarine and two helipads. It's also incredibly secure; it has a missile detection system and bulletproof windows.



Lady Moura

Saudi businessman Nasser Al-Rashid's \$210-million (£159-million) Lady Moura has six decks and can carry a crew of 60 and 30 guests. It has a spa, a casino and even an operating theatre in case of emergencies.



Rising Sun

American entertainment magnate David Geffen owns this \$200-million (£151.4-million), 138-metre-long superyacht. Its amenities include a movie theatre, helipad, basketball court and an extensive wine cellar.

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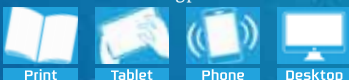


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How does power steering work?

A system of pressurised fluid helps you turn the weight of your car with ease

If you've ever used a car without power steering you'd have known about it quite quickly – it is difficult to heave the weight of the vehicle around corners without this system of hydraulics to assist you.

Power steering operates in the same way as standard rack and pinion steering systems (which turn the rotational motion of the steering wheel into linear motion to turn the wheels) but with a modified rack forming a hydraulic piston and cylinder arrangement.

When you turn your steering wheel to the left or right, high-pressure fluid is forced into one side of the cylinder. This action moves the piston attached to the steering gears, turning the car's front wheels in the direction you want to move.

Fluid lines

These tubes carry hydraulic fluid into the cylinder – while one injects fluid on one side of the piston the other vents the fluid out on the opposite side.

Rotary control valve

This senses the force being exerted on the steering wheel and ensures hydraulic assistance is only provided when the vehicle is turning and not when it's driving in a straight line.

Hydraulic pump

This pump pressurises the fluid entering the power steering system by using a series of rotating retractable vanes.

Piston

The piston is moved by the fluid, either to the left or the right as the car is steered, and it pushes the rack along with it.

Torsion bar

This metal rod twists when the steering wheel is turned, moving the pinion gear right or left to turn the wheels.

The mechanics behind power steering

A modified rack and pinion system provides hydraulic boosts to the steering gear

The Schwyz-Stoos funicular railway

This space-age Swiss Alpine train uses unique technology to scale the side of a mountain

This magnificent funicular railway may look futuristic, but it has been engineered as a solution to an old problem. It connects the towns of Muotathal, Morschach and Schwyz with Stoos – a small mountain village that is 1,300 metres above sea level. The train carries passengers through 1.74 kilometres of beautiful snow-topped pine trees using four 34-passenger rotating cabins on an incline of up to 110 per cent. Each cabin is fitted with stabilisation technology, which keeps the floors horizontal during ascent and descent and adjusts to incline changes throughout the journey.

Funicular railways are a fusion of elevator and railroad technology that are used to transport people and cargo up challengingly



It takes the Standseilbahn Schwyz-Stoos three to five minutes to complete one trip

steep hills and mountainsides. Wheeled vehicles would struggle with traction, but funiculars are pulled up the side of the mountain using a cable to overcome this problem. The wheels are primarily there to guide the car along the rail rather than offer



The funicular provides panoramic views of the mountainside throughout the journey

any active movement. This ingenious design of a funicular means that one set of cabins is balancing the weight of the other, with one on each side of the top pulley. This means that as one car starts descending, its weight helps the ascending car on its climb.



The future of smart roads

One stretch of highway has been transformed into a test-bed for cutting-edge road technologies

Motorways around the world are being tested to the limit. With more vehicles on the roads than ever before and new technologies changing the way they operate, infrastructure must adapt to support the increased load and evolve with our advanced cars. Whether they're electric or autonomous, or they run on biofuel or solar power, roads and vehicles need to evolve together in order to pave the way for a sustainable future.

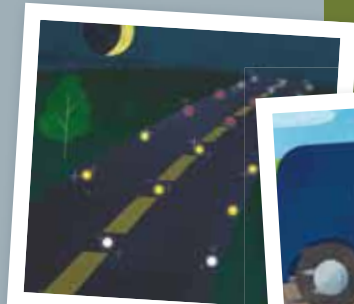
One project pioneering this idea is The Ray in Troup County, Georgia, US. Built on a 29-kilometre section of Interstate 85, The Ray is a working test site for the new advanced systems that will deliver the smart roads of tomorrow.

The future

Other ideas in the pipeline at The Ray include smart studs, which improve on current road reflectors. These solar-powered lights would be able to illuminate in different colours to convey different messages to drivers, such as upcoming junctions or dangerous conditions ahead.

Another technology being considered is electric charging lanes, which would charge a car's battery as it drives along by electromagnetic induction. This would mean that drivers could charge up without having to stop on their journeys. However, it would be an expensive project, so the team at The Ray have not yet made a final decision about pursuing this idea.

The Ray has been designed as a 'living laboratory' to test out these innovative technologies. Hopefully, many of the current and future trials will prove successful and we'll start to see smarter roads all over the world.



The Ray is a 29km section of the Interstate 85 highway in Georgia

The Ray

What technologies can be found along this hi-tech highway?

Bioswales

These shallow drainage ditches are planted with vegetation or filled with compost to slow water that runs off from the road as well as capture particles of pollutants such as rubber and oil. The Georgia Department of Transportation has worked with a number of landscape engineers and ecologists to select native plant species that can clean the water and mitigate some of the effects of traffic pollution.



The bioswales will help to control and clean the highway's water runoff during rainstorms

Farming in the hard shoulder

The key to innovative smart road designs is to utilise space as much as possible. The right-of-way (the land around the highway) can double up as farm land. Crops here can clean water runoff and capture carbon.



Kernza wheatgrass was planted in a 93m² plot by The Ray in October 2017. It will be harvested as a fibre source for products like paper towels

Climate modelling

The team behind The Ray have teamed up with Resilient Analytics to assess the vulnerability of this section of highway to the effects of climate change. The teams can analyse this information, alongside case studies and historical data, to determine the risks and come up with plans to reduce the damage in response to changes in precipitation and temperature.



Data from the project can help the team adapt to the challenges of a changing climate, thereby helping them to improve highways

Solar-powered vehicle charging

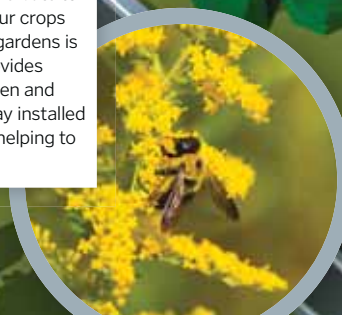
A PV4EV (photovoltaic for electric vehicle) solar-powered charging station has been installed at the West Point Visitor Information Center. It can charge a typical electric car to 80 per cent of its total power in just 45 minutes. Eco-friendly charging stations like this will help support the growing number of electric cars on our roads, which currently lack sufficient infrastructure.



The solar-powered charging station on The Ray opened in October 2015 and was the first of its kind in Georgia

Pollinator garden

We need pollinators such as bees and bats to keep our ecosystems thriving and our crops healthy. Planting pollinator-friendly gardens is not only visually pleasing, it also provides these creatures with sources of pollen and nectar. The team working on The Ray installed a 650m² pollinator garden in 2016, helping to give local wildlife a boost.



Over two-thirds of crops worldwide depend on pollinators

Tyre safety check station

The clever roll-over WheelRight Tire Pressure Monitoring System on The Ray means drivers don't even need to stop to check their pressure manually. Instead, they just drive over a sensor in the road and the system sends them a text with information about the condition of their tyres.



In the US, it is estimated that over 7.5 billion litres of fuel per year are wasted due to underinflated tyres

Solar-paved highway

The Wattway is the result of five years of research and collaboration between transport infrastructure leaders Colas and the French National Institute for Solar Energy. A 50m² section of The Ray is paved with solar panels, providing a clean, renewable source of energy while still allowing traffic to pass.



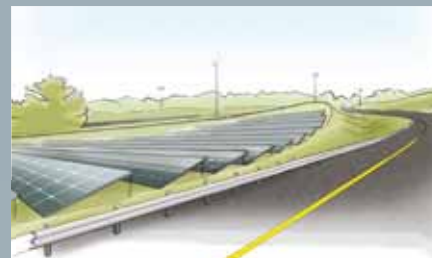
The Wattway was installed at the West Point Visitor Information Center in 2016

Technology coming soon



Solar barriers

The team at The Ray want to combine solar panels with various systems. They are looking to develop solar-panelled sound barriers that will reduce noise pollution while also generating electricity.



Right-of-way solar

Georgia has plenty of sunshine and space, so the developers behind The Ray are installing solar panels in the right-of-way of the highway. This project is due to be completed in December 2019.



Drones

Utilising drones may be one of the next steps in the project. These can be used to monitor the highway by inspecting bridges, surveying new road areas and analysing the extent of damage after extreme weather events.



Rubber roads

The Ray is due to be repaved next year. The team are determined to experiment with nontraditional materials and are investigating the viability of quiet and flexible rubber roads.

Decrypto

Outfox your opponents, communicate secretly and crack their codes in this game of misdirection

The pressure's on. You've got a handful of words and a string of numbers, and you need to give the clues that'll help your teammates link them up, but across the table the enemy is listening in. Be careful which three words you pick. Too obscure, and your friends won't decipher the message; too obvious, and your opponents can easily crack the code. Welcome to *Decrypto*.

Take away the paraphernalia – the floppy-disc clue tokens, the red-tinted plastic that makes your clue words swim out from a fuzz of colour – and this is a word game of fabulous simplicity. Each team has four words: in our example Team A has Winter, Monk, Time and Nose. Each

clue-giver, or Encryptor, will draw a card with a three-number sequence like 4,3,1.

The Encryptor then gives three clues to their team – say, Poke, Doctor, Chill – and the team writes down what they hope is the right number sequence. If they think it's "poke your nose in", "Doctor Who the Time Lord" and "winter's chill", and get 4,3,1, they're right.

Now the enemy gets a chance to intercept. If they get it right, they draw an Interception token; if the home team gets it wrong, they draw a Miscommunication token. The teams then repeat the process, taking turns and keeping notes until one team has two Interceptions and wins, or two Miscommunications and loses.

- Publisher: Le Scorpion Masqué
- Price: £16.99 / \$19.95
- Number of players: 3–8
- Ages: 12+
- Typical game time: 15–45 mins



Evade and intercept

I spy with my little eye...
cracking strategies for
cunning code-breakers

Tick, tock

When one Encryptor has her clues, she flips an hourglass, giving her opponent limited time to finish his own.

Write that down

Successful Decryptors keep notes. You'll need to check your guesses against the code card at the end of the round.

Body of knowledge

It's helpful to keep a record of the clues on each word, but watch out – the enemy's doing the same!

The other side

After one round the sides switch. Now White will hear Black's clues and try to break them. Good luck.

Words of wisdom

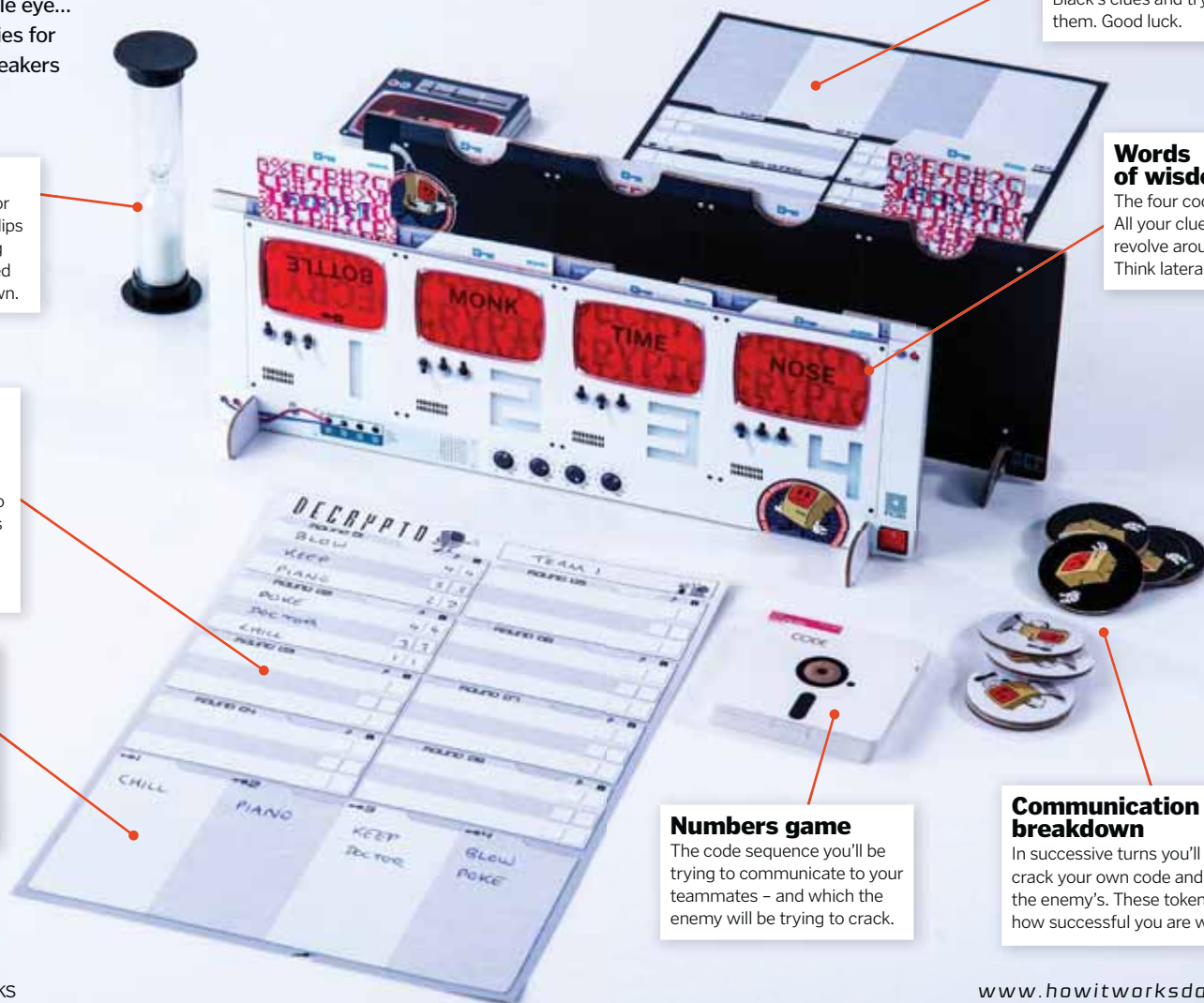
The four code words. All your clues will revolve around these. Think laterally!

Numbers game

The code sequence you'll be trying to communicate to your teammates – and which the enemy will be trying to crack.

Communication breakdown

In successive turns you'll try to crack your own code and break the enemy's. These tokens track how successful you are with each.



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BRAIN DUMP



Because enquiring minds need to know...

Red meat leaves small scratches on teeth, while bone leaves deep dents

MEET THE EXPERTS

Who's answering your questions this month?



JODIE TYLEY



TOM LEAN



LAURA MEARS



JAMES HORTON



JO STASS

Why did the sabre-toothed cats go extinct?

Becky Lawrence

■ The jury is still out. Sabre-toothed cats disappeared at the end of the last ice age, and the most popular reason for their demise is that climate change and competition with humans meant that they struggled to find enough food. However, researchers from

Vanderbilt University in the US have examined teeth preserved in the La Brea tar pits in California and they disagree. Microscopic patterns in the teeth revealed that feeding activity barely changed between 35,000 and 11,500 years ago. **LM**

The Russian empress ruled for more than 30 years

Who was Catherine the Great?

Niamh Ashton

■ She's Russia's longest-ruling female leader, but Catherine II was actually Prussian and named Sophie at birth. During her reign (1762–1796) Russia conquered new territories and expanded its borders well into central Europe. Her interests in education and culture saw a school for girls established, and she also founded the Academy of Language that produced Russia's first dictionary. Her art collection can still be seen in the Hermitage Museum in St Petersburg. All of her achievements earned her the title 'great'. **JT**

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The Tesla Cherry Roadster is currently cruising through the Solar System

Could Elon Musk's 'Starman' Roadster ever collide with Earth?

Becki Aksakova

■ Since it blasted off into space as the centrepiece of SpaceX's Falcon Heavy inaugural launch, Elon Musk's Tesla Roadster has entered an orbit that intersects both the orbits of Mars and Earth. Although it will pass close to within one lunar distance of its home planet in 2091, scientific estimates have put the chances of the Roadster colliding with Earth at just six per cent over the next million years. **JH**



Do we really need eight hours of sleep?

Yvette Martin

■ The amount of sleep needed varies between individuals and age groups; children need more sleep than adults, for instance. In general, many studies show that about seven to nine hours is ideal for adults, with evidence of increased health risks among those who regularly sleep much less or more than this. **TL**

The 33rd World Bog Snorkelling Championships will take place on 26 August 2018



What is bog snorkelling?

Li Wei Tang

■ Bog snorkelling is a sport invented in Wales in 1976. It involves swimming as quickly as possible through a very murky peat bog trench wearing a snorkel and flippers. The World Bog Snorkelling Championships have been taking place every August in Llanwrtyd Wells in Wales since 1985

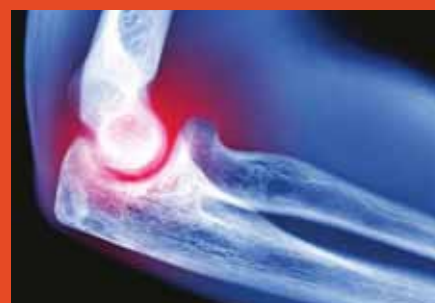
and attract hundreds of competitors from all over the world. The current world champion is Neil Rutter, who managed to swim the 110-metre-long course in 1 minute and 26.15 seconds in 2017, but the World Record was set by Kirsty Johnson in 2014 with a time of 1 minute and 22.56 seconds. **JS**



What are 'sea monkeys'?

Reece Gibbons

These popular pets are a breed of shrimp. They are able to adopt a state of suspended animation, meaning their eggs can be dried and then resurrected in water. **JH**



What is tennis elbow?

Brianna Hannam

Overusing muscles and tendons in the elbow can cause pain, which is known as 'tennis elbow' as the sport works many of the associated muscle groups. **JH**



Is it true that spiders prefer to live in clean houses?

Rob Shaw

Not really. Clearing away food debris that attracts the insects spiders like to eat may help deter them, as would removing any existing cobwebs and minimising dark spaces they could hide in. **JS**



What is ruby chocolate?

Ivy Miles

Ruby chocolate is a new type of chocolate made from ruby cocoa beans. It was developed by Barry Callebaut, the world's largest cocoa processor. It's naturally pink in colour with a fruity taste. **JS**



The Earth's rotation is slowing due to the gravitational influence of the Moon on tides

Is it true that Earth's rotation is slowing down?

Molly Ingram

■ Astronomers have discovered that the Earth's rotation is gradually slowing down. This is largely caused by the influence of the Moon, whose gravity causes tides in the Earth's oceans. Friction between these tides and the spinning Earth causes the planet's rotation to slow. With each passing century the Earth takes about two milliseconds longer to rotate, making days longer as time passes. Scientists think that a day 350 million years ago would have been less than 23 hours long. TL

E-cigarettes deliver nicotine without the harmful chemicals found in tar

Is vaping really any better for you than smoking?

Dennis Weiss

■ There is no doubt that smoking is bad for your health, but the health effects of e-cigarettes are less clear cut: they just haven't been around long enough. However, research so far is promising. Nicotine itself doesn't cause cancer, and e-cigarettes don't contain the same harmful chemicals as traditional tobacco cigarettes. A study funded by Cancer Research UK found significantly lower levels of toxic chemicals in the bodies of ex-smokers using e-cigarettes or nicotine replacement therapy compared to smokers. Even so, recent work also found that chemicals in e-cigarette vapour can damage the DNA of cells in test tubes. We still don't know if the same is true in people. LM



What's the difference between raisins, currants and sultanas?

Tegan Lourde

The first two are dried naturally, giving them a dark hue. Sultanas have a golden hue as they're treated with sulphur dioxide. JT



How do television stations know their viewer numbers?

Johnnie Ellis

The Broadcasters' Audience Research Board monitors 5,100 homes that represent the UK's demographics and locations. Each TV is fitted with a meter. The data recorded is weighed to represent the whole of the UK. JT



Is it bad for your health to sleep close to your phone?

Jax Hilton

Mobile phones emit radio waves. Scientists have been studying their effects since the 1990s, and current evidence doesn't show a link with health problems. That said, research is still ongoing. LM



How does antifreeze work?

Jake Poole

Simply by lowering the freezing point of water. Antifreeze chemicals, like ethylene glycol, methanol and trehalose, dissolve in water and reduce ice-crystal formation. LM



Want answers?

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Have humans ever come close to extinction?

Benjamin Larsen

Today, our species numbers over 7 billion, but we haven't always had it so easy; our genetic code tells a tale of a species once fraught with peril. Given the ample time that has passed since our Homo ancestors diverged from their chimpanzee relatives (around 5 million years) we would expect there to be substantial genetic diversity across our species, which is curiously absent. This has been explained by a severe reduction in the gene pool around 1 million years ago, which came as a result of the Homo population being reduced to mere thousands in number. So, at least on one occasion, our kind has teetered on the brink of extinction. **JH**

What is the difference between a comet and an asteroid?

Aaliyah Butler

Both are objects that orbit the Sun, but comets are made of ice, dust, rocky material and organic compounds, while asteroids are made of metals and rock. Asteroids are mainly found in the 'asteroid belt' between the orbits of Mars and Jupiter, while comets are found in the furthest reaches of the Solar System. Also, comets form tails as their ice melts and vaporises when they get close to the Sun, but asteroids don't. **JS**

Comets can be seen from Earth with tails of vaporised material trailing behind them



A female blackbird collecting nesting materials

How do birds build their nests?

Fern Brown

Each species has their own techniques, but they share similar tools of the trade. Avian architects rely on natural materials such as twigs, grasses or even holes in trees or roofs. They use their beaks to position their materials, aided by a flexible neck and good eyesight, and they usually 'glue' the structure together with mud, spider webs or saliva. The nest starts off as a few twigs and blades of grass dropped on top. As these layers build up the bird turns in the nest and weaves new strands into the side. This action creates the classic cup shape. **JT**

What are guitar strings made of?

Mike Braun

Early guitar strings were made of animal intestine and silk, but today they are normally made of modern materials, including polymers such as nylon and metals like steel and bronze. **TL**



© Getty, Wiki/NASA

How do they dock cargo ships with the ISS?

Leanne Cartwright

There are several different cargo spacecraft used to supply the ISS, but whatever type is being used, it takes hours of careful manoeuvring using thrusters to bring the cargo ship into the right place for docking and at the right speed. Once near to the ISS, some cargo ships, such as the Russian Progress spacecraft, use a computerised system to automatically move the ship to connect with a docking port. Other cargo craft, such as the Japanese HTV, are positioned close to the ISS, then the crew uses a robotic arm to grab the spacecraft and attach it to a docking port. **TL**



An HTV cargo spacecraft being grabbed by a robotic arm during docking on the ISS

BOOK REVIEWS

The latest releases
for curious minds

The Book of Comparisons

Change your view by sizing up the world around you

- Author: Clive Gifford
- Publisher: Ivy Kids
- Price: £14.99 (approx. \$20)
- Release date: Out now

Science can be incredibly engaging, but at times certain facts can be hard to grasp. How small is a tiny human egg before it's fertilised? Pluto is small so it has lower gravity, but how high could you jump if you were on its surface? Finding a simple comparison can sometimes take the mystery out of the mysterious and make information like this easier to understand, which is why *The Book of Comparisons* is so compelling. Gifford finds some brilliant stats to compare and in the process simplifies science. Did you know, for example, that while the human body is around 50–60 per cent water, the actual amount of water in an adult man's body is about the same as 47.5 one-litre bottles of water?

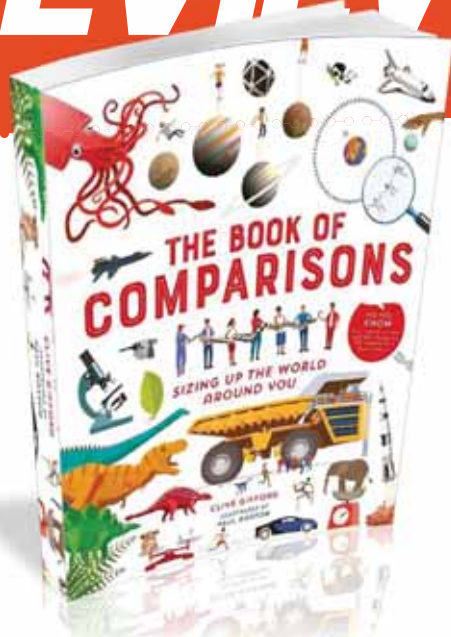
Each of these facts is brought wonderfully to life by Paul Boston's beautiful illustrations; his unique, colourful and engaging style helps bring some character to even the more standard comparisons. Every page is filled with images, from animals and plants to planets and human creations. Smart decisions help you to make sense of each fact, like a wave that weighs the

same as 110 SUVs looking like, well, 110 SUVs in the shape of a wave. They're simple ideas, but they work brilliantly in context.

One thing that's worth noting is that this is for a slightly younger audience of science lovers. It's aimed at ages seven and up, but the writing, facts and comparisons mean it may not hold the attention of older readers for more than a short time. Other similar books pack in more details or encourage you to read more by explaining an idea in brief before moving on. Because of the nature of this book, though, once you've read the comparison you have all the information you need. This is great for younger readers, who otherwise may leave frustrated, but it's one of the reasons why older readers may well be turned away.

However, there's still plenty to like about this big book of facts, and if younger readers *do* pick it up they'll undoubtedly be sharing the wilder facts over the dinner table. Let's just hope it's not the one about the dung beetle that can push 1,141 times its body weight in poop.

★★★★★



At Least Know This: Essential Science to Enhance Your Life

Answering the big questions one by one

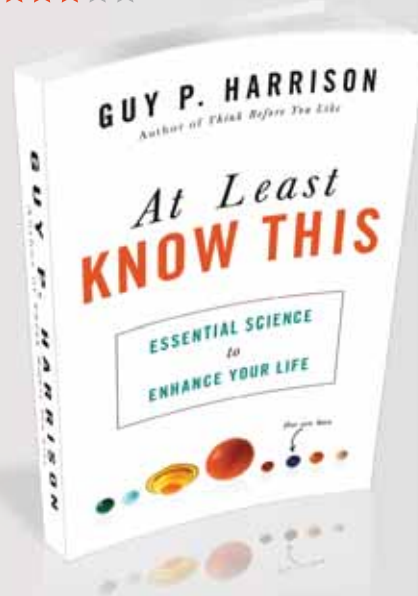
- Author: Guy P Harrison
- Publisher: Prometheus Books
- Price: £15.99 / \$19
- Release date: 20 July (UK) / 17 July (US)

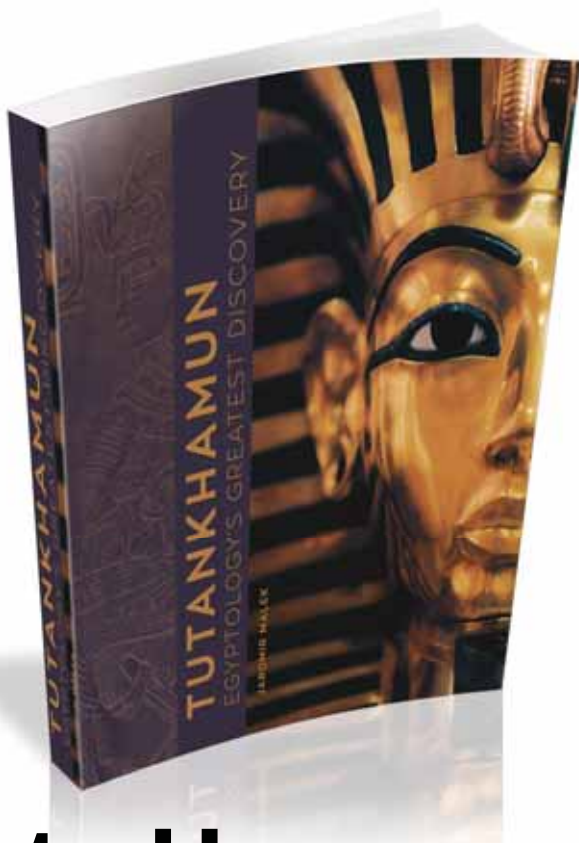
While humankind has made some truly great strides with regards to technology and medicine, in other areas it appears to have stagnated. We wilfully engage in practices that we know harm the planet, continue to kill each other in wars and resolutely refuse to work together to improve life for everyone.

It's ironic that while science has been responsible for some of our greatest advances, it continues to remain mistrusted in certain fields. It is therefore only fair that science gets the right of reply in this book, tackling ten primary areas of knowledge that cover such varied topics as life's earliest beginnings, the miracle of the human brain and the basis behind some of Earth's most destructive feuds.

While there are plenty of useful nuggets of information, other areas really needed more space (a few paragraphs on why excessive use of antibiotics may prove to be catastrophic could definitely have been expanded upon). Regardless, Harrison's rebuttal to worry is competent enough.

★★★★★





Tutankhamun: Egyptology's Greatest Discovery

Behind the scenes of the ancient boy king's tomb

- Author: **Jaromir Malek**
- Publisher: **Andre Deutsch**
- Price: **£25 (approx. \$33)**
- Release date: **Out now**

Famous more for the groundbreaking nature of the discovery of his tomb than because of his actual rule, Tutankhamun has captured the popular imagination arguably more than any other pharaoh, which makes a book about his life and the importance of his discovery an appealing prospect.

In truth, however, there is little information about the prince himself here – in all honesty, there isn't a huge amount that is known about him. Rather, this book takes the form of an annotated pictorial

history of Egypt, with Tutankhamun's reign serving as context. In this respect there is little to separate this from the numerous other books about ancient Egypt out there, the exception being that this could serve usefully enough as a coffee-table read, and the story of his tomb's excavation is always a captivating one.

So while this wasn't necessarily the read we might have been expecting, it is nonetheless a lovingly presented one.

★★★★★

"Tutankhamun has captured the popular imagination"

The Art of Logic: How to Make Sense in a World That Doesn't

The equation of life

- Author: **Eugenia Cheng**
- Publisher: **Profile Books**
- Price: **£14.99 (approx. \$20)**
- Release date: **Out now**

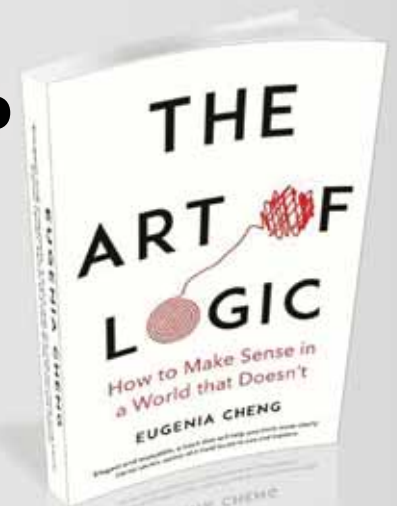
Few fields are as avowedly logic-based as mathematics, but considering how complicated it can get, this doesn't always come across. We're thankful, then, that someone like Eugenia Cheng is here; someone to eloquently and efficiently expound on concepts like logic and truth at a time when their very basis seems to come under daily attack.

It may not be immediately obvious how mathematics can be applied to understand recent headline-grabbers like Donald Trump, Black Lives Matter

and Me Too, but here the case is made for it being essential. The strength of an argument can best be measured by the degree to which it allows you to come round to someone else's point of view, and it's certainly a case of mission accomplished here.

We're forever on the lookout for someone to make mathematics both fun and accessible, and it looks like we've found that person in Eugenia Cheng.

★★★★★



Light of the Stars: Alien Worlds and the Fate of the Earth

Space – the first frontier

- Author: **Adam Frank**
- Publisher: **W W Norton & Co Ltd**
- Price: **£20 / \$26.95**
- Release date: **13 July (UK) / Out now (US)**

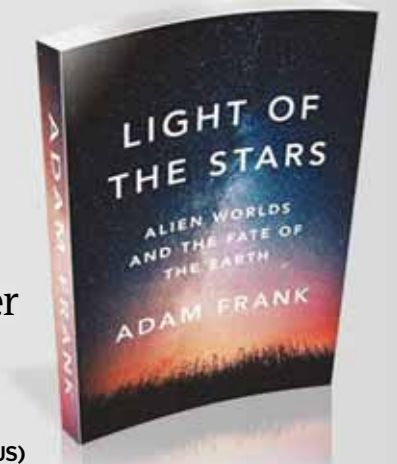
As far as we know, we are alone in the universe. That doesn't preclude the possibility that life may have once existed in our immediate vicinity, but as it stands we're flying the flag for the known universe.

A professor of astrophysics at the University of Rochester, not to mention a prolific online blogger and commentator, Adam Frank is well placed to shed light on the history of the universe and our possible future within it, which is the focus here, with Frank examining various

environmental phenomena on nearby planets – not to mention our own – and judging the findings of some of Earth's earliest and most renowned figures who have attempted to understand what exactly is out there.

Pleasingly, the findings here are more hopeful and proactive than has been the case elsewhere, encouraging us to take charge and create a better future. As far as messages go, it's not a bad one.

★★★★★



BRAIN GYM

GIVE YOUR BRAIN A PUZZLE WORKOUT

Wordsearch

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | I | L | F | M | K | N | C | O | E | P | L | G | B | H |
| J | E | A | R | T | H | G | H | V | Y | T | O | Q | N | E |
| D | R | N | X | U | Z | W | A | T | D | Q | E | M | R | D |
| E | H | D | T | A | S | E | R | Y | M | Z | V | E | C | Y |
| G | O | S | J | P | I | B | N | R | G | H | O | G | M | L |
| N | Q | L | V | S | T | M | I | C | H | E | L | A | D | A |
| I | S | I | X | M | H | Q | A | F | J | I | V | S | U | M |
| R | Y | D | N | A | C | P | R | L | G | M | E | H | G | A |
| E | H | E | F | R | A | K | T | H | I | O | Z | A | N | R |
| E | S | U | N | T | Y | C | T | W | X | E | A | R | I | R |
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| E | R | E | H | P | S | O | M | T | A | C | E | B | S | L |

FIND THE FOLLOWING WORDS...

ALIENS
ATMOSPHERE
CANDY
CHARNIA
DNA
EARTH
ENGINEERING
EVOLVE
HEDYLAMARR
LANDSLIDE
LIGHT
MEGASHARKS
SIGN
SMARTROAD
STEERING
STMICHEL
SUPERYACHT
TASER
TESS
TUMBO

Quickfire questions

Q1 The site of Windsor Castle was chosen by:

- ☐ Elizabeth I
- ☐ Richard the Lionheart
- ☐ Bloody Mary
- ☐ William the Conqueror

Q2 Which protein is hair made of?

- ☐ Keratin
- ☐ Actin
- ☐ Kérastase
- ☐ Biotin

Q3 'Laser' stands for Light Amplification by...

- ☐ Stimulated Excitation of Radiation
- ☐ Stimulated Emission of Radiation
- ☐ Stimulated Excitation of Radio waves
- ☐ Simulated Emission of Radiation

Q4 When were the first Nobel Prizes awarded?

- ☐ 1895
- ☐ 1901
- ☐ 1905
- ☐ 1911

Spot the difference

See if you can find the six changes we've made to the image on the right



Sudoku

Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9

EASY

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 4 | | 5 | | 1 | | 3 | 6 | |
| 1 | 7 | | 4 | | | 8 | 2 | |
| 9 | 8 | 6 | | 5 | 2 | | 1 | |
| | | | | 3 | 4 | 6 | 7 | 1 |
| 6 | 1 | 7 | 9 | | 5 | 4 | | 8 |
| | 3 | | 1 | | 7 | 5 | 9 | 2 |
| 7 | | | 6 | 4 | 1 | 2 | 5 | 3 |
| | | 1 | | | 3 | 9 | | 7 |
| 3 | 4 | 2 | | | 9 | 1 | | |

DIFFICULT

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| | | | | 7 | | | | |
| 9 | 4 | | | | | | | 8 |
| | | | | 6 | 8 | | 3 | |
| | | | 1 | | | | | 6 |
| | | | | | 4 | 2 | 1 | |
| | 3 | | 2 | 5 | 9 | | | |
| | | 3 | | 1 | | 6 | | |
| | | 2 | | | 5 | 4 | | 1 |
| | 9 | 1 | | | | | | 7 |

What is it?

Hint: Comes in several colours; a messenger of the gods in Greek mythology

A



For more brain teasers and to test your problem-solving abilities, try our *Mensa Puzzle Book*, which is packed with problems and puzzles designed by experts at Mensa.

Available from myfavouritemagazines.co.uk



Spot the difference



Check your answers

Find the solutions to last issue's puzzle pages

Quickfire questions

- Q1** Oxygen
- Q2** 23.5°
- Q3** Roman king of the gods
- Q4** Fédération Internationale de Football Association

What was it?

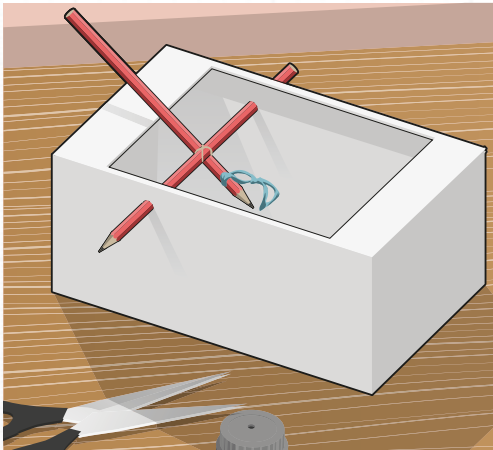


Bread

Make a tissue box catapult

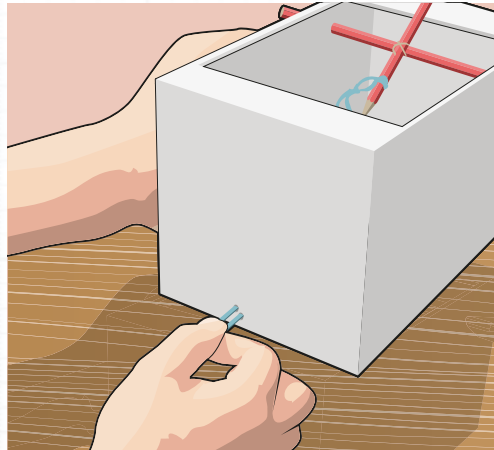
Launch things like LEGO bricks and pom-poms with this simple elastic catapult

DON'T DO IT ALONE
IF YOU'RE UNDER 18, MAKE SURE YOU HAVE AN ADULT WITH YOU



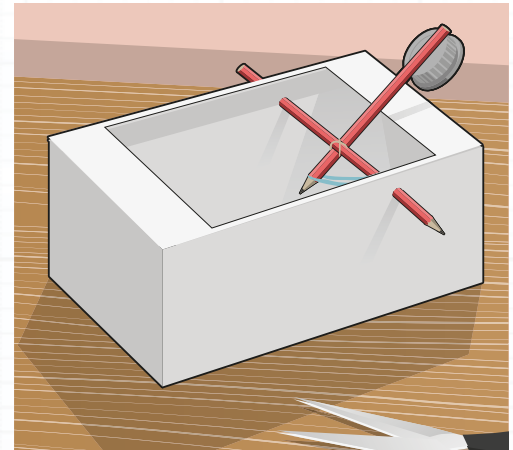
1 Build the base

Find a large tissue box or a small shoebox that's structurally strong – if there are any open or weak areas, tape them together to make it more solid. Cut a rectangular hole in the top of the box and carefully make a hole in each side of it with a sharp pencil. Use an elastic band to attach two pencils together to form a cross, then poke each side of its 'arms' through the box holes, as shown.



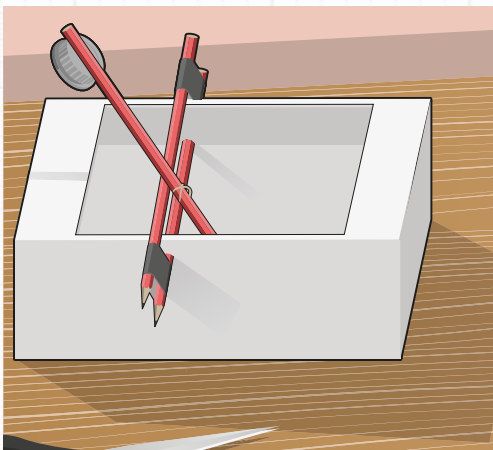
2 Create the pull

Wrap another elastic band around the bottom of the loose pencil, then make another small hole in the back of your box. Push the elastic band through, then push another pencil (or something long and thin like a pipe cleaner) through the loop that's sticking out. You might need to use tape to secure this to the outside of the box. Now you've got power for your catapult.



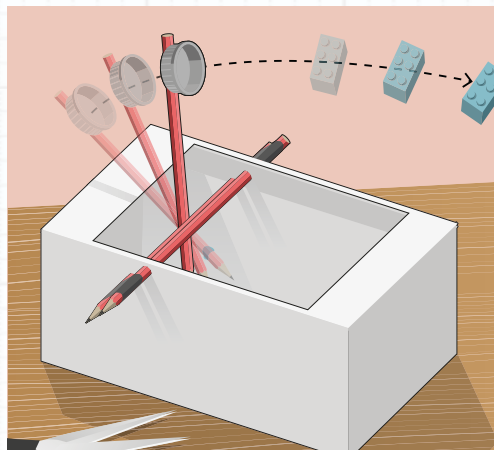
3 Add a cap

Next, you will need to create a grip for the things that you want to fling! You can use a milk bottle top for this. Using hot glue, carefully attach the bottle top to the pencil. This will give you the best grip, but you can also use a section cut out of an egg box and a combination of sticky tack and tape if you don't have hot glue to hand. If you're under 18 then ask an adult to help you.



4 Make a stopper

Your catapult will work now, but without a stopper it won't fire things very far. Use duct tape to attach another pencil to the first pencil over the top of the box, as shown above. That way, when the catapult reaches a certain point, the stopper pencil will hit the box, and the catapult will hit the stopper. When the arm stops moving the item inside will keep its energy and go flying!



5 Time to fire!

Now you can load up your catapult and start firing. Try using different items, like small LEGO bricks, pom-poms or anything else you have around your house. Which items travel further, and why? You can also change the tension of your elastic band by attaching two smaller ones together or by using one large band. How does it affect how far your items fly?

"When the arm stops moving the item inside will go flying!"

In summary...

When you pull back on the arm of the catapult you are transferring potential energy to the elastic band. When you let go of the arm this potential energy turns into kinetic energy as the elastic pulls the arm backwards. The item in the grip has this energy too, and when the arm stops moving the item keeps going!

Disclaimer: Neither Future Publishing nor its employees can accept any liability for any adverse effects experienced during the course of carrying out these projects or at any time after. Always take care when handling potentially hazardous equipment or when working with electronics and follow the manufacturer's instructions.

Experiment with static electricity

See what static electricity can do with these fun experiments

NEXT ISSUE
MAKE EGGSHELL
GEODE CRYSTALS
HAVE A LIGHTSABER
DUEL



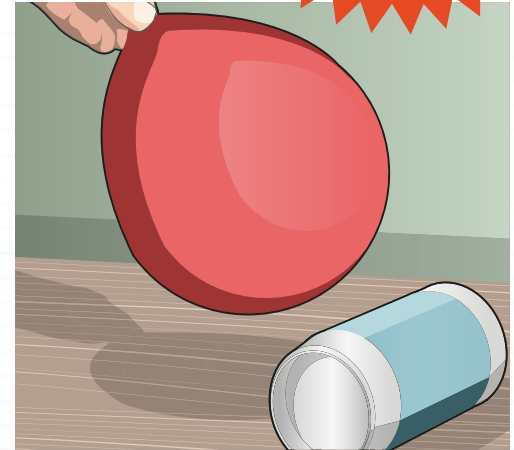
1 Charge it up

Static electricity can be generated using a woolly jumper, or even your hair. It can be held in all kinds of items too, so there are plenty of things around your home that can be used. Find a comb and use it to brush your hair. After a few brushes, raise the comb a little and you'll see that strands of hair are being attracted to the comb!



2 Water experiment

You can do a similar test using water. Turn on a tap and make sure your comb still has some charge. When there is a steady flow of water, move your comb closer to the stream and the water will bend towards it. When you comb your hair, tiny charged particles called electrons are transferred to the comb. These have a negative charge.



3 Rolling a can

Because the comb has a negative charge it's attracted to positively charged items. The comb's charge is powerful enough to attract the positively charged particles in the water. You can try the same thing with a can and a balloon. Lie the can on its side, rub a balloon on your hair, hold the balloon close to the can and watch it roll closer!

"The water will bend towards the comb"

In summary...

The water and the can have positive and negative charge, but when the comb or balloon get close, the electrons attract the positive particles, pulling them closer. The negative particles in the water and the can move to the other side as they are repelled by the negative electrons.

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For your chance to win, answer this question on our website:

What does the word 'meghalodon' mean?

- a) **Big shark**
- b) **Big jaws**
- c) **Big tooth**

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Droid-to-droid
BB-9E can interact with other Sphero *Star Wars* App-enabled droids

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BB-9E rolls around just like in the films

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Sundogs are a concentrated area of light seen 22° to the right and left of the Sun



Letter of the Month

A strange solar sighting

Dear HIW,

We were wondering if you could identify what these unusual rainbows and three 'Suns' in the sky were. We saw them on Friday 18 May at around 7:11pm. I hope you can help us.

Thank you,

Tessa Dodd and Erin Beresford

What you have witnessed is known as a 'sundog'. Under the right conditions, the Sun can appear to have a heavenly halo with two new 'Suns', one sitting either side of it. This optical illusion is caused by the refraction of light through ice crystals in high and cold

cirrus clouds. When the hexagonal ice crystals align vertically, they act like a prism, bending the light rays passing through them. As the light is refracted, bursts of rainbow light may be seen. This phenomenon is also known as parhelia, and it can occur at any time of the day or year, however, it is more commonly seen as the Sun approaches the horizon in cooler temperatures. Labelled as 'mock Suns' by the ancient Greek philosopher Aristotle (384-322 BCE), it's reported that the ancient Romans actually used sundogs as a way of forecasting rainfall. The Moon can also experience 'lunar dogs' when similar conditions are met.

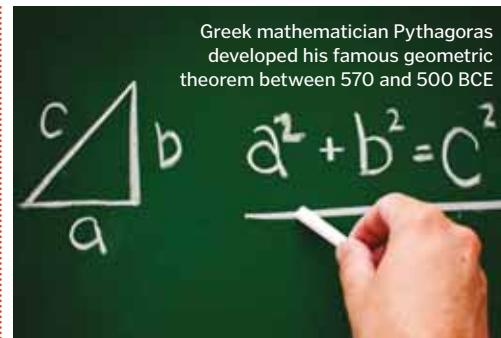


WIN!

AMAZING PRIZE FOR LETTER OF THE MONTH!

EUREKA: HOW INVENTION HAPPENS

Discover the story behind five key inventions of modern times and explore the breakthroughs, innovations and eccentric personalities that led to each 'eureka moment'



Greek mathematician Pythagoras developed his famous geometric theorem between 570 and 500 BCE

Numbers + time = maths

Dear HIW,

I was wondering how mathematics originated? It seems a big leap from counting to modern maths.

Thanks,

Theodore Sinclair

You're correct, it is a big leap, but humans have had around 50,000 years to hone their numerical skills. The evolution of mathematics ran parallel to the evolution of human civilisation. Over time, as our inquisitive minds and capabilities grew, so did our mathematical abilities. Numbers offered solutions to the problems we used to face as a species, from working out the seasons for agriculture to the geometry of building our homes. Complex algebraic maths dates right back to around 1750 BCE in ancient Egypt, and since then our understanding of the world, and the mathematical principles we use to express it, have expanded. We can now use maths to calculate the nature of subatomic particles and the workings of the wider universe.



Déjà vu all over again

Was it déjà vu, or a glitch in The Matrix?

Dear HIW,

It was a very clever idea to repeat the article on déjà vu ('Have you read this before') in issue 111 after it originally appeared in issue 110 (page 58). Our whole family reads HIW and we all had a great laugh at this. Cheers,

Paul Bouloudas



Roman burial

Dear **HIW**,

It's known that Roman soldiers died by the thousands in battle, but what happened with the bodies after battle? Thanks,

Felipe Ledesma

Roman soldiers buried their dead near their camps. Depending on the number, this could have been either in individual or mass graves. Some of these graves have since been uncovered, such as the remains of 13 potential Praetorian Guards during the construction of Rome's metro line expansion in 2016.



Mysterious bubbles

Dear **HIW**,

I am new to the magazine and I would like to say that I love it! It is always full of new and exciting facts and even if I did know some of them, it's still very impressive. My question is, what are the bubbles in water (after it has been left overnight) and are they harmful to us?

Thanks,
Charlie Finn

These tiny bubbles are simply atmospheric gases previously trapped in the water that escape as the water is left out for a few hours. As the water temperature gradually rises from cold (out of the tap) to room temperature overnight, tiny bubbles of these gases come to the surface. But don't worry - they are completely harmless.



Nitrogen and oxygen bubbles form at imperfections on the glass due to a change in temperature

© Getty

www.howitworksdaily.com

What's happening on...

social media?



This month we asked you... As humans are still evolving, what abilities would you like to develop?

"I would evolve into a creature that could fly. It would be so handy!"
@RustedTulips

"Sitting here waiting for a blood test, I wish I had evolved with a tap, so no needle required!"
@Esmith10000

"A mermaid!! Although I'm afraid of the ocean water"
@BeeAMarkie

"Someone a bit taller...I seem to have a height of a person from the Middle Ages lol"
@CompigCodyboy

"I'd like to evolve to be super smart, super fast and super strong. Not much to ask for, surely?"
@tyler_wendy



Highlights from the Twitterverse

"It's #EndangeredSpeciesDay! #Species #extinction is occurring at up to 1,000 times the natural rate, and the world has lost half of its #wildlife in just 40 years. This is the time to shout about it and call for action!"
@WildlifeDay

"Don't sweat the technique. This weekend, I plan to add percussion to a new drilling method devised by the team. Looking forward to taking samples for science again on #Mars."
@MarsCuriosity

"46,000 years ago, Neanderthals sat on the beach in Spain, eating limpets and sea urchins. Yum!"
@theAliceRoberts

"#FOTD In the battle for mating rights, Bighorn sheep rams collide at speeds of 40mph. The clash of two rams' horns during a fight can be heard up to a mile away."
@SteveBackshall

HOW IT WORKS

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Amazing trivia to blow your mind

SWEDEN OPENED THE
WORLD'S FIRST ELECTRIFIED
ROAD TO CHARGE ELECTRIC
VEHICLES IN APRIL 2018

THE LAST COMMON ANCESTOR OF HUMANS AND
CHIMPANZEES LIVED AROUND

6-7 MILLION YEARS
AGO

THERE CAN BE A DIFFERENCE OF

15 METRES

BETWEEN LOW AND HIGH TIDE AT
THE MONT SAINT-MICHEL BAY

**140,
000**

THE NUMBER OF NATIVE RED
SQUIRRELS LEFT IN THE UK

200+

DIFFERENT SIGN LANGUAGES ARE
USED GLOBALLY

THE HELICOPRION
HAD A BIZARRE

360°

SPIRAL OF
SERRATED TEETH

1 IN 5

INVASIVE SPECIES ARE
THOUGHT TO CAUSE HARM
TO THEIR NEW HABITATS

PALAEONTOLOGISTS
ESTIMATE THAT
MEGALODONS COULD
GROW TO LENGTHS OF

18M

COOKING WITH SUGAR IS VERY
TEMPERATURE DEPENDENT: IT
CAN CREATE FUDGE AT 115°C,
TOFFEE AT 140°C AND LIGHT
CARAMEL AT 165°C

22 million

THE AMOUNT OF MAN-HOURS TO BUILD THE BURJ KHALIFA

GREAT WHITE
SHARKS MUST SWIM
CONTINUOUSLY TO
VENTILATE THEIR GILLS

AT LEAST

75%

OF YOUR DNA IS USELESS
- IT DOESN'T CODE FOR ANY
FUNCTIONAL PROTEINS

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MARS LOSES
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